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Pacific Northwest Laboratory Annual Report for 1981 to the DOE Office of the Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness

Part 5 Environmental and Occupational Protection, Assessment, and Engineering

February 1982

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Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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PNL-1981 Environment, Health and Safety Part 5

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Pacific Northwest Laboratory Annual Report for 1981 to the DOE Office of the Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness

Part 5 Environmental and Occupational Protection, Assessment, and Engineering

W. A. Glass and Staff Members
of Pacific Northwest Laboratory

February 1982

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

This 1981 annual report from Pacific Northwest Laboratory (PNL) to the Department of Energy (DOE) describes research in environment, health, and safety conducted during fiscal year 1981. The report again consists of five parts, each in a separate volume.

The five parts of the report are oriented to particular segments of our program. Parts 1 to 4 report on research performed for the DOE Office of Health and Environmental Research in the Office of Energy Research. Part 5 reports progress on all research performed for the Office of the Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness. Each part consists of project reports authored by scientists from several PNL research departments, reflecting the interdisciplinary nature of the research effort. Project reports in Parts 1 to 4 are organized primarily by energy technology.

The parts of the 1981 Annual Report are:

Part 1: Biomedical Sciences	
Program Manager - H. Drucker	D. L. Felton, Editor
Part 2: Ecological Sciences	
Program Manager - B. E. Vaughan	B. E. Vaughan, Report Coordinator C. M. Novich, Editor
Part 3: Atmospheric Sciences	
Program Manager - C. E. Elderkin	R. L. Drake, Report Coordinator N. M. Burleigh, Editor
Part 4: Physical Sciences	
Program Manager - J. M. Nielsen	J. M. Nielsen, Report Coordinator I. D. Hays, Editor
Part 5: Environmental and Occupational Protection, Assessment, and Engineering	
Program Managers - D. L. Hessel S. Marks W. A. Glass	W. A. Glass, Report Coordinator R. W. Baalman, Editor

Activities of the scientists whose work is described in this annual report are broader in scope than the articles indicate. PNL staff have responded to numerous requests from DOE during the year for planning, for service on various task groups, and for special assistance.

The topic of the 21st Hanford Life Sciences Symposium, which was held this year, was "Biological Availability of Trace Metals: Chemical Estimation, Ecological and Health Implications."

A highlight of the year was completion of the third floor of the office wing of the Life Sciences Laboratory. This opens up substantial laboratory space by allowing investigators to move offices from the laboratory to the new area.

Credit for this annual report goes to many scientists who performed the research and wrote the individual project reports, to the program managers who directed the research and coordinated the technical progress reports, to the editors who edited the individual project reports and assembled the five parts, and to Ray Baalman and Irene D. Hays, editors in chief, who directed the total effort. The size of this year's report has been reduced as the result of an effort to report more fully in the open literature.

W. J. Bair, Manager
S. Marks, Associate Manager
Environment, Health and Safety Research Program

Previous Reports in this series:

Annual Report for

1951	W-25021, HW-25709
1952	HW-27814, HW-28636
1953	HW-30437, HW-30464
1954	HW-30306, HW-33128, HW-35905, HW-35917
1955	HW-39558, HW-41315, HW-41500
1956	HW-47500
1957	HW-53500
1958	HW-59500
1959	HW-63824, HW-65500
1960	HW-69500, HW-70050
1961	HW-72500, HW-73337
1962	HW-76000, HW-77609
1963	HW-80500, HW-81746
1964	BNWL-122
1965	BNWL-280; BNWL-235, Vol. 1-4; BNWL-361
1966	BNWL-480, Vol. 1; BNWL-481, Vol. 2, Pt. 1-4
1967	BNWL-714, Vol. 1; BNWL-715, Vol. 2, Pt. 1-4

1968	BNWL-1050, Vol. 1, Pt. 1-2; BNWL-1051, Vol. 2, Pt. 1-3
1969	BNWL-1306, Vol. 1, Pt. 1-2; BNWL-1307, Vol. 2, Pt. 1-3
1970	BNWL-1550, Vol. 1, Pt. 1-2; BNWL-1551, Vol. 2, Pt. 1-2
1971	BNWL-1650, Vol. 1, Pt. 1-2; BNWL-1651, Vol. 2, Pt. 1-2
1972	BNWL-1750, Vol. 1, Pt. 1-2; BNWL-1751, Vol. 2, Pt. 1-2
1973	BNWL-1850, Pt. 1-4
1974	BNWL-1950, Pt. 1-4
1975	BNWL-2000, Pt. 1-4
1976	BNWL-2100, Pt. 1-5
1977	PNL-2500, Pt. 1-5
1978	PNL-2850, Pt. 1-5
1979	PNL-3300, Pt. 1-5
1980	PNL-3700, Pt. 1-5

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FOREWORD

Part 5 of the 1981 Annual Report to the Department of Energy's Office of Environmental Protection, Safety and Emergency Preparedness presents Pacific Northwest Laboratory's progress on work performed for the Office of Environmental Programs, Office of Operational Safety, and the Office of Nuclear Safety. The report is in three sections, introduced by blue divider pages, corresponding to the program elements: Technology Impacts, Environmental and Safety Engineering, Operational and Environmental Safety.

In each section, articles describe progress made during FY 1981 on individual projects, as identified by the Work Package Proposal and Authorization System. Authors of these articles represent a broad spectrum of capabilities derived from various segments of the laboratory, reflecting the interdisciplinary nature of the work.

For additional information on any of the projects reported in Part 5, contact the authors of the articles.

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Technology Impacts

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TECHNOLOGY IMPACTS

- **Technology Assessment***
- **Regional Impacts**

The integrated technology overview program, funded by the Department of Energy, Office of Environmental Assessment, is a mechanism by which health, environmental, social, economic, and institutional factors are combined into a form useful for energy planning and decision making. This program selectively combines information about the potential effects of alternative energy technologies (such as waste releases, land and water use, and social effects) and about constraints on the development and use of these technologies to produce broad-based assessments of the advantages and disadvantages of energy and conservation policy options. As a corollary, needs for further research, development, and technology transfer are identified.

Technology Assessment projects focus on respective energy production technologies. These projects evaluate the readiness of these technologies for commercial application and the likely consequences of their deployment under appropriate national energy and environmental policy assumptions.

The Regional Impacts projects are designed to improve analytical methodologies; facilitate the collection, storage, and transmission of energy and environmental information; and project gross national and regional environmental effects associated with national policy options. The Regional Impacts component of the Office of Environmental Assessment considers in some detail the consequences of various national energy policy alternatives as represented by scenarios in which a portfolio of energy technologies is considered to be deployed in the region. At PNL these assessments are directed at the four Pacific Northwest states—Alaska, Washington, Oregon, and Idaho. The regional work includes characterization of the region as it is now, identification and assessment of regional issues, and possible approaches to mitigation of regional problems interfering with implementation of national policy.

*Bullets denote Field Task Proposal/Agreement (FTPA) titles.

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• Technology Assessment

Work in Technology Assessment considered a variety of energy technologies. Some of this work was directed toward the preparation or revision of brief Environmental Development Plans and Environmental Readiness Documents. Other work focused on major technology assessments. The products of both types of effort are used by the Department of Energy for adopting a position on further development and application of respective energy technologies, and on other energy policy matters.

TECHNOLOGY ASSESSMENT OF OIL SHALE

D. L. Hessel

Oil Shale is a resource of great potential significance to the United States. The major oil-shale deposit in the country, the Green River Formation of Colorado, Wyoming, and Utah, contains the equivalent of two trillion bbl of oil. That portion of the resource with greatest economic potential, averaging 25 or more gal/ton of rock, contains the equivalent of some 600 billion bbl. By comparison, the U.S. domestic petroleum reserves were estimated at about 30 billion bbl in January 1978. However, the shale oil potential is tempered by physical limitations on the rate of production, long lead time for technical development, and high costs.

No method of shale oil production has been demonstrated beyond the scale of 1000 bbl/day. Numerous uncertainties exist about the physical and economic suitability of developing current processes to commercial-sized plants of 10,000 to 50,000 bbl/day. As with other energy technologies based on fossil fuels, production and use of shale oil pose controversial questions about possible undesirable effects on the natural environment, agriculture, and human health and safety.

The oil-shale assessment described here was undertaken: 1) to provide a comprehensive, objective review of shale oil technologies as a means of supplying domestically produced fuels within acceptable limits for environmental, social, economic, and legal/institutional impacts; 2) to examine the major points of uncertainty regarding potential impacts in light of all reasonably available data, analyses, and experienced judgment; 3) to resolve issues when data and analyses are compelling or where conclusions can be reached on judgmental grounds; and 4) to specify issues that cannot be resolved using only the data, analyses, and experienced judgment currently available.

Since most of the rich oil shale lies in northwestern Colorado, northeastern Utah, and southwestern Wyoming, this assessment focuses on its development in that area. Various above-ground and modified in-situ retorting processes are incorporated in a hypothetical, but realistic, technological mix as a basis for analysis. This mix is designed to produce 300,000 bbl/day when fully implemented, assumed to be about 1990 or 1995. Rigorous consideration of these technologies at this scale will result in recognition of most of the potential significant impacts of a mature shale oil production industry. The assessment considers these impacts in the categories of effects on media (air, surface water, ground water, and land); ecosystems and agriculture; human health and safety (primarily occupational); social and economic systems; and legal/institutional systems.

An interdisciplinary team of scientists and recognized oil-shale authorities conducted this assessment. These individuals were drawn from Pacific Northwest Laboratory (PNL), universities, consulting firms, and several other Department of Energy (DOE) laboratories. All work on this assessment was completed in FY 1981; final reports were prepared for distribution.

TECHNOLOGY ASSESSMENT OF THE ENVIRONMENTAL, HEALTH, AND SAFETY ISSUES ASSOCIATED WITH THE COMMERCIALIZATION OF UNCONVENTIONAL GAS RECOVERY

E. F. Riedel

Efforts to find more natural gas have intensified over the past decade. As the more conventional geologic resources are being depleted, other more unconventional ones are receiving more attention. However, before these latter resources can add significantly to our nation's supply of natural gas, we must examine the public health and safety, environmental, economic, and legal/political consequences and constraints that might be

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associated with these resources and technologies. This assessment focuses on potential public health and safety problems, potential environmental impacts, legal/institutional constraints, and other potential barriers to commercialization.

The objective of this project is to identify all barriers to the commercialization of unconventional gas recovery (UGR). The commercialization of four resources is being evaluated:

- western tight-gas sands
- methane associated with coal seams
- eastern Devonian-age shales
- methane contained in geopressured aquifers.

This study was completed in FY 1981 with the publication of the final reports on eastern Devonian-age shales by PNL and the final report on methane contained in geopressured aquifers by Lawrence Berkeley Laboratory. DOE may use the results to rank the commercialization effort for the development of these resources.

ENVIRONMENTAL DEVELOPMENT PLANS AND ENVIRONMENTAL READINESS DOCUMENTS

C. A. Geffen

The Technology Assessment Division in the Office of the Assistant Secretary for Environment prepares Environmental Readiness Documents (ERD) as statements of its evaluation of the prospects for respective technologies. These documents are updated every year or two to keep abreast of changes in the status of the technologies and of knowledge about potential effects of these technologies.

During FY 1981, PNL completed a draft of the Environmental Readiness Document for Unconventional Gas Recovery. This ERD identified the primary potential environmental, health, and safety concerns for development of unconventional gas resources that may require further attention to utilize these resources in an environmentally acceptable manner.

Review of available literature and recent technology assessments predict no significant environmental or health and safety concerns that might present serious obstacles to continued development of unconventional gas resources. Some need exists to continue development of control technologies to adequately control potentially toxic waste fluids so that workers and the public will not be excessively exposed.

TECHNOLOGY ASSESSMENT OF SOLAR ENERGY

A. D. Chockie, W. J. Hopp, K. J. Allwine, P. N. Petty

Pacific Northwest Laboratory has been involved, together with other DOE laboratories, in a multiyear assessment of the impacts associated with the maximum practical use of solar conversion technologies in the year 2000. This national assessment effort was divided into regional assessments; PNL was responsible for investigating the environmental and socioeconomic impacts in the Pacific Northwest (Washington, Oregon, and Idaho). In the process of examining these impacts from maximum use of solar technologies in the Northwest, a level specified by the presidential domestic policy review, we concluded that the impacts associated with the biomass technologies were considerably more severe than those of the other relatively benign solar technologies. Therefore, in FY 1981, PNL's solar assessment concentrated on the use of Northwest biomass resources.

The Pacific Northwest is endowed with extensive biomass resources primarily in the form of agricultural and forest residue. Although a large part of the forest residue is presently consumed by the forest products industry, a significant quantity of forest and agricultural material could be used as a fuel. In FY 1981, PNL undertook an assessment of this material to determine its availability and the impacts associated with its use.

Although current estimates indicate that existing biomass resources are equivalent to one-quarter to one-third of the total Northwest energy consumption, there are numerous factors that will tend to significantly constrain their use as fuel resources. These factors include such things as terrain conditions, collection logistics, soil nutrient requirements, and the reduction of virgin timber stands. An extensive list of such factors is reported in Technology Assessment of Solar Energy Systems: Availability and Impact of Woody Biomass Utilization in the Pacific Northwest (Hopp, Chockie, Allwine 1981). Of the various forms of biomass material potentially available, it was determined that forest residues would be the primary biomass fuel resource in the Northwest. In this report, a preliminary analysis was made of four particularly important issues: the competing end-uses for the biomass material; policies of the U.S. Forest Service concerning forest residue; injuries and deaths associated with the collection of the material; and the regional air quality

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degradation from the use of biomass fuel. A major conclusion from this analysis was that the most serious environmental and socioeconomic impacts from the use of biomass fuel result from the collection and burning of wood in residential wood stoves.

Technology Assessment of Solar Energy Systems: Residential Use of Fuelwood in the Pacific Northwest (Petty and Hopp 1981) assesses four major issues associated with residential firewood use: the energy balance of wood use, residential fire risks, air quality degradation, and the hazards involved in firewood collection. The assessment of the hazards of collecting firewood and the degradation of Northwest air quality were also presented separately in two papers at the 1981 International Conference on Residential Solid Fuels.

The results of these activities indicate that, if the use of wood in the residential sector continues as projected, there will be significant winter air quality problems in many Northwest metropolitan areas, serious environmental impacts on the forests surrounding the major population centers, and a large number of related injuries and deaths. Without public awareness, voluntary compliance, and some public policy changes, these will be the major impacts from an ambitious program for the development of solar conversion technologies in the Pacific Northwest.

REFERENCES

Hopp, W. J., A. D. Chockie and K. J. Allwine. 1981. Technology Assessment of Solar Energy Systems: Availability and Impact of Woody Biomass Utilization in the Pacific Northwest. PNL-3933, Pacific Northwest Laboratory, Richland, Washington.

Petty, P. N. and W. J. Hopp. 1981. Technology Assessment of Solar Energy Systems: Residential Use of Fuelwood in the Pacific Northwest. PNL-3918, Pacific Northwest Laboratory, Richland, Washington.

TECHNOLOGY ASSESSMENT OF ENHANCED OIL RECOVERY

E. F. Riedel

Enhanced oil recovery (EOR), sometimes referred to as tertiary oil recovery, is one of the energy technologies that offers promise in the near term of helping the United States decrease its dependency on foreign oil. It has been estimated that as much as two million bbl/day of tertiary oil could be produced by the year 2000. This quantity represents about 25% of all current domestic production.

Enhanced oil recovery includes most processes that inject fluids, other than natural gas and brine, into a reservoir. Large quantities of petroleum (as much as 95% for heavy crudes to 30% for a light crude reservoir) normally remain in a reservoir following primary and secondary production. These large amounts of remaining oil are the target of EOR.

EOR processes include miscible fluid injection, chemical flooding, and thermal methods. Thermal processes include in-situ combustion, cyclic steam injection, and steam drive. Miscible fluid injection is usually carbon dioxide flooding, although liquified petroleum gas (LPG) and other fluids that are miscible with crude oils have been used. Chemical flooding is the injection of certain complex fluids to recover oil. Among the most popular methods are polymer flooding, caustic flooding, and miscellar-polymer flooding.

The objective of this program is to evaluate the environmental risks and consequences of projected EOR activities in the near and long term. Equal emphasis is being given to all primary EOR activities. Results will be used by the Department of Energy to evaluate the overall risk/consequences from the commercialization of EOR.

This is a multilaboratory project involving PNL, Lawrence Berkeley Laboratory, and Brookhaven National Laboratory. PNL's primary responsbility is to provide technical information on oil-field practices and operations associated with EOR. Since FY 1980, the primary focus of this project has been to identify and evaluate potential environmental concerns associated with EOR technologies. A three-day workshop titled, "Enhanced Oil Recovery Workshop: Problems, Scenarios and Risks," was held to receive a wide range of input in these areas. In addition to participating in the workshop, PNL staff prepared a projection of the use of enhanced oil recovery techniques to the year 2000. The proceedings of the workshop were published in FY 1981. The final report will be published early in FY 1982.

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• Regional Impacts

The work for FY 1981 was directed in two main areas. First, Pacific Northwest Laboratory (PNL) continued work to improve long-range transport models for predicting the dispersion of oxides of nitrogen over a region. Second, PNL provided the lead laboratory function for identifying institutional problems related to the handling and storage of radioactive wastes.

LONG-RANGE TRANSPORT OF NITROGEN OXIDES

W. J. Eadie, K. J. Allwine, R. L. Drake

The effects on air quality that may result from the application of energy technologies require study and evaluation. Pacific Northwest Laboratory (PNL) has recently completed a comparison of trajectories using long-range transport models computed by PNL and Brookhaven National Laboratory (BNL). Overall, the PNL and BNL models compared well except during periods of disturbed weather. Because both models use layer-averaged winds and do not account for vertical motion, neither model will perform accurately when influenced by frontal systems.

Pacific Northwest Laboratory has also contributed to DOE's "Nitrogen Oxides in the Atmosphere: Energy/Environment Information Handbook," primarily in the areas of long-range transport processes and atmospheric modeling. A brief overview of these contributions follows.

- Long-Range Transport of NO_x

Long-range transport of nitrogen oxides and their reaction products is an area of substantial uncertainties. Chemical and physical transformation processes occur resulting in the oxidation of NO to NO_2 and the formation of other reaction products such as HNO_3 and aerosol nitrates. Wet and dry deposition are occurring and may play an important role in the removal of HNO_3 and aerosol nitrates. Broad similarities in the geographic distribution of airborne sulfates and nitrates over the United States have been shown. In addition, similarities in distribution of $SO_4^=$ and NO_3^- in precipitation in the northeastern United States have been observed. What differences exist are most likely due to variations in source distributions, transport distances, and chemical transformations.

- Trajectory Model Calculations of Long-Range Transport of NO_x

Preliminary application of a variable trajectory model to the long-range transport of NO_x used a first-order chemical transformation of NO_2 into nitrates. NO_x emissions were assumed to be NO_2, and were converted to HNO_3. Results for the "nitrate" air concentrations are considerably higher than observed concentrations. The computed wet deposition yielded NO_3^- concentrations in precipitation somewhat below concentrations measured by the MAP3S precipitation chemistry network. Closer results may have been achieved if spatially varying transformation rates had been used.

- Long-Range Transport Modeling of NO_x

Models with the potential for describing the long-range transport of NO_x and reaction products are classified as grid, or Eulerian models and trajectory, or Lagrangian models. Reference frames fixed at the surface are called Eulerian, and these models better describe influences of topography, detailed meteorology, and reactive pollutants from many sources. A frame fixed on pollutant puffs is called Lagrangian, and these models are more capable of describing passive emissions from several sources using simple chemistry.

--Trajectory Models

Lagrangian, or trajectory models, are simple and economical to run for a limited number of sources or agglomeration of sources and have been used to study long-range transport of SO_2. However, for describing long-range transport of nitrogen oxides and their reaction products, these models have significant limitations because only first order chemistry can be treated.

--Grid Models

Eulerian or grid models for long-range NO_x transport are based on solving transport and diffusion equations on fixed three-dimensional grid systems by finite difference approximation or other numerical methods. These models are more complex and sophisticated than Lagrangian models and require large computer resources and extensive data bases.

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- Deposition Processes

Gases and particles are removed from the air by both precipitation (wet) and dry impaction (dry). Dry deposition is the direct transfer of materials from the atmosphere to the earth's surface by absorption, adsorption, and chemical fixation, using mechanisms such as gravitational settling, transport by atmospheric turbulence, impaction, and chemical reactions. Wet deposition, or scavenging, is the removal of materials by precipitation; it occurs below clouds during precipitation events, and in clouds during the formation and growth of cloud droplets.

--Deposition of NO_x

Wet and dry deposition of nitrogen oxides and their reaction products are not well understood. Limited studies show neither NO nor NO_2 is efficiently scavenged by precipitation. It has been shown that NO may be removed through dry deposition; dry deposition is also an important removal mechanism for NO_2. It is believed that both wet and dry deposition is important in the removal of HNO_3. Because of the paucity of evidence regarding dry deposition of HNO_3, wet deposition appears to be the principal removal mechanism.

- Mesoscale Transport

Mesoscale transport is the regime spanning the region between short-range and long-range transport. Effects such as land-and-sea-breeze circulations, urban heat island circulations, and a wide spectrum of complex terrain influences such as valley-mountain circulations and flows over mountain ranges fall into the mesoscale transport area.

- Diurnal Variation of NO_x

The variations with time of NO/NO_2 concentrations at any point are dependent on many time-varying events including the locations and emission rates of NO_x sources, the photochemical reactivity of the air (presence of reactive hydrocarbons), solar intensity, wind speed, wind direction, temperature, relative humidity, and synoptic/mesoscale meteorology.

In the vicinity of an urban area, the diurnal variation in the NO/NO_2 concentration typically takes on the following forms. A peak occurs corresponding to the morning rush-hour traffic. As the traffic is tapering off, the sun causes photochemical reactions to begin and vertical mixing increases dilution. The concentration of both NO and NO_2 drops off rapidly followed by a gradual increase in NO_2 concentrations throughout the afternoon. The NO levels stay low because of photochemical conversion to NO_2 and subsequently to other nitrogen-containing compounds. In the evening and night, NO may increase or remain fairly constant depending on the presence of O_3 or other oxidizing agents.

INSTITUTIONAL ANALYSIS LEAD LABORATORY

F. A. Morris

This project assists the Office of Environmental Programs and the laboratories and contractors working for it in addressing institutional issues.

This year's research focused on four areas of radioactive waste management:

1. Policy issues in radioactive waste management. This research investigated policy issues in three components of the Federal waste management program: terminal isolation of high-level waste, interim storage of spent fuel, and low-level waste management. For each of these three components, we focused on firmly established policies resulting from statutes or final regulations, current policies established by presidential announcements or program decisions by Federal agencies, and unresolved policy issues.

2. Institutional and socioeconomic issues in radioactive waste management. This work investigated nontechnical problems in the field of radioactive waste focusing on key issues associated with high-level waste isolation, interim spent fuel storage, and low-level waste management.

3. Forming, operating, and maintaining interstate compacts for low-level waste management: institutional design issues. This research included a review of political science literature to distill lessons for the formation, operation, and survival of interstate compacts for low-level waste management.

4. Use of siting criteria to address social concerns over hazardous waste facilities. Ways were researched of designing the siting processes of hazardous facilities to further public acceptance.

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Environmental
and Safety
Engineering

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ENVIRONMENTAL AND SAFETY ENGINEERING

- **Assessment of Synfuel Cleanup Options**
- **Liquefied Gaseous Fuels Safety Studies**
- **Oil-Burning of Spills**
- **Environmental Control Technology for Shale Oil Analysis**
- **Compressed Air Energy Storage (CAES) Environmental Concerns**
- **Analysis of Nuclear Fuel Cycles**
- **Analysis of Fusion Fuel Cycle**

The objective of the Environmental and Safety Engineering Program is to assure that the environmental control capability for each DOE energy technology is complete, practical, cost-effective, and available in a timely manner as the energy source is developed. Program activities are oriented to identifying control technology status and needs for emerging energy systems, then developing methods and equipment for meeting these needs.

Pacific Northwest Laboratory's effort in this program grew rapidly through 1981. During 1981 we conducted studies in support of both nonnuclear and nuclear technologies with programs in oil shale, oil, coal, synfuel, gas, compressed air energy, and analysis of nuclear fuel cycles.

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• Assessment of Synfuel Spill Cleanup

Synfuel products are expected to have physical properties similar to their counterparts derived from natural petroleum. However, the biological activity, toxicity, and subsequent resistance to biodegradation may be considerably higher in selected synfuel components than in petroleum-based products and can vary widely. Therefore, techniques and methodologies to handle synfuel spills must be identified and assessed.

ASSESSMENT OF SYNFUEL SPILL CLEANUP OPTIONS

W. Wakamiya, B. W. Mercer

The objective of this project is to assess and report on spill cleanup options for synfuels that are projected to reach commercial production by the year 2000. This study compares the various synfuel products with their corresponding petroleum-derived products to determine a relative spill hazard potential and recommend control/cleanup procedures appropriate to the anticipated ecological effects. Projected production, storage, consumption, and transportation modes in the United States were investigated to identify potential sources of uncontrolled releases of synfuel products. The existing methodologies for handling petroleum spills were used as a guide for synfuel-related incidents. Modifications necessary to make petroleum cleanup procedures applicable to synfuels were identified. Laboratory and field testing were recommended as required to verify preferred spill cleanup procedures.

Production forecasts were prepared for synfuel crudes and products to the year 2000. These forecasts were based on the most current information available from government agencies and private entities involved in synfuel development, production, or marketing. Quantities of synfuels spilled were estimated from the production forecasts and the data on petroleum spillage. Methods of storage, transportation, and consumption for synfuel products and for their petroleum-derived counterparts are expected to be similar. Therefore, historical data on spillage of petroleum products were also used to determine potential sources of synfuel spillage.

Physical, chemical, biological, and ecological properties of synfuels (when available) were compared with their counterparts. This permitted tentative identification of problems unique to synfuel spills. Potential spill hazards of synfuel were then assessed based on these data.

Current and developing technologies for treatment and cleanup of oil and hazardous material spills were reviewed, and their applicability to synfuel spills was evaluated. Recommendations were made for laboratory and field testing programs to verify the effectiveness of any modification in established spill cleanup procedures or to test new procedures.

Disposal methods for spill residuals from hazardous material were reviewed and evaluated for applicability to synfuel spill residual. Synfuel crudes and products may be considered hazardous if disposal of spill residual is required. Disposal methods for synfuel spill residual were recommended from this evaluation.

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• Liquefied Gaseous Fuels (LGF) Safety Studies

The objectives of this project are 1) to conduct research and development in specific areas of the DOE Liquefied Gaseous Fuels (LGF) Safety and Environmental Control Assessment Program and 2) to provide assistance to the DOE/EP Environmental and Safety Engineering Division in the planning and technical surveillance of the program. The FY-1981 project combined studies conducted previously in the Liquefied Natural Gas (LNG) Safety Studies Project and the Liquefied Petroleum Gas (LPG) Safety and Environmental Research and Development Project. The combination of these projects into the current LGF Safety Studies Project corresponds to the evolving emphasis of the DOE Program.

Several task and milestone reports were completed in FY 1981, including a scoping assessment of LNG release prevention and control systems; detailed assessments of LNG release prevention systems in representative peak-shaving facility and an import terminal; and reviews of LNG fire and vapor control systems, human factors engineering, and LNG storage tank technology. Two major tasks, the Ammonia Safety and Environmental Control Assessment, and the Assessment of LPG Research and Development Needs were completed. Literature surveillance and the development of the LNG library continued. Finally, a special study was undertaken to show that water may be useful as a simulant for investigating LGF rapid phase transition phenomena.

LIQUEFIED GASEOUS FUELS (LGF) SAFETY STUDIES

J. G. DeSteese, D. L. Brenchley,
C. A. Counts, W. E. Davis, A. L. Franklin,
P. J. Pelto, W. L. Rankin, R. Shikiar
E. G. Baker, W. C. Cliff, T. E. Gates,
B. A. Fecht

The Environmental and Safety Engineering Division of the Department of Energy, Office of Environmental Protection, Safety and Emergency Preparedness (DOE/EP), is conducting the DOE Liquefied Gaseous Fuels (LGF) Safety and Environmental Control Assessment Program. The object of this assessment is to gather, analyze, and disseminate technical information that will aid future decisions made by industry, regulatory agencies, and the general public relating to facility siting, systems operations, and accident prevention and mitigation. This LGF program is coordinated with the efforts of other agencies and is supported by research at national laboratories and technical institutions and by private contractors. The LGF Safety Studies Project, conducted by the Pacific Northwest Laboratory (PNL), combines two previously separate projects: the LNG Safety Studies Project and the LPG Assessment Project. This combined project provides research on LNG release prevention and control, planning assistance, and technical surveillance in support of the DOE/EP Program. Many of the safety and environmental issues identified for LNG apply also to the handling of other liquefied gaseous fuels such as liquefied petroleum gas (LPG) and ammonia. As part of the LGF project, PNL is providing assessments that evaluate safety and environmental control issues relating to production, transportation, storage, and use of LPG and ammonia. The PNL project is structured around five major tasks:

- LNG Release Prevention and Control Studies
- LNG Technical Surveillance
- Ammonia Safety and Environmental Control Assessment
- Assessment of LPG Research and Development Needs
- Special Studies.

Progress in these tasks is summarized below.

LNG Release Prevention and Control Studies

P. J. Pelto, A. L. Franklin, W. L. Rankin,
R. Shikiar

The objective of the LNG Release Prevention and Control Task is to develop an adequate understanding of LNG release prevention and control systems, and the factors that may defeat them. Work in FY 1981 in the LNG Release Prevention and Control Studies focused on six subtasks: 1) Facility Scoping Studies, 2) Import Terminal Analysis, 3) Peakshaving Plant Analysis, 4) Storage Tank Analysis, 5) Fire Prevention and Control Assessment, 6) Human Factors Analysis.

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- Facility Scoping Studies

P. J. Pelto

A report outlining the results of a scoping assessment of LNG release prevention and control systems was prepared and published (Pelto et al. 1981). This report characterizes the basic types of LNG facilities and their release prevention and control systems; identifies possible weak links and research needs; and provides an analytical framework for more detailed analyses. Building upon this scoping assessment, PNL initiated more detailed assessments of LNG import terminal and peakshaving facility release prevention and control systems. Studies have also been initiated on LNG storage tank operations, LNG fire and vapor control systems, and human factors in LNG operations.

- Import Terminal Analysis

E. G. Baker

An assessment of import terminal release prevention systems was completed. This assessment considered the frequency and quantities of release events identified in the scoping assessment. Important release prevention components were identified, and the effects of alternative designs were examined. A paper describing the results of the import terminal analysis was presented at the 1981 Cryogenic Engineering Conference (Baker and Pelto 1981).

- Peakshaving Facility Analysis

P. J. Pelto

A more detailed assessment was made of release prevention systems in LNG peakshaving facilities. This assessment is similar in scope to that of the import terminal.

- Storage Tank Analysis

B. A. Fecht, T. E. Gates

A comparative safety analysis of LNG storage tanks was completed. Representative aboveground metal and concrete tanks were defined and their responses to release-initiating events compared. Release-initiating events under consideration include overfill, overpressure, underpressure, foundation failure, crack propagation, earthquake, tornado, impact, and adjacent fires. These comparisons were quantified to the extent that available information permits.

- Fire and Vapor Control Assessment

A. L. Franklin

A study was completed of the state-of-the-art of fire and vapor control equipment used in the LNG industry. The assessment of LNG fire and vapor control devices continued. The reference import terminal and peakshaving facility provided the framework to examine the reliability and effectiveness of current fire and vapor control strategies.

- Human Factors Analysis

R. Shikiar, W. L. Rankin

Current practices in human factor engineering (HFE) in the LNG industry were reviewed in the literature and at several peakshaving plants. To assess the potential contributions of HFE to LNG safety, previous LNG accidents and incidents were analyzed for impacts from human error. We conclude from this phase of the study that factors such as operator training, operating and maintenance procedures, alarms and warnings, and controls and displays are generally worthy of further examination. This analysis was supported by two example fault trees taken from a system safety analysis of LNG import terminals. These fault trees demonstrated important entry points for consideration of human factors in the LNG industry.

LNG Technical Surveillance

W. E. Davis, C. A. Counts

The objective of the LNG Technical Surveillance Task is to assist DOE in establishing and maintaining technical surveillance of research and development activities related to LNG safety and environmental control. Literature surveillance and development of a LNG library continued. Four quarterly supplements to the "LNG Annotated Bibliography" and additions to the "LNG Safety and Control Literature and Research Updates" were completed and distributed to the sponsor and other contractors. A survey of information contained in European LNG literature continued under a subcontract performed by Battelle-Institut e.V. in Frankfurt, West Germany.

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Ammonia Safety and Environmental Control Assessment

D. L. Brenchley

The objective of this task was to contribute program planning information by identifying potential problem areas relating to ammonia safety and environmental control. This effort was initiated in FY 1979 and completed this year.

The final assessment report was published (Brenchley et al. 1981) and includes: 1) a characterization of the ammonia industry, 2) a review of current knowledge of ammonia release and dispersion phenomena and impacts, 3) the identification of safety and environmental problems, and 4) recommendations for research and development (R&D) to mitigate these problems.

A number of recommendations, including the following, resulted from this assessment:

- Additional work should be undertaken to develop an understanding of the causes of explosions that occur in ammonia storage and transportation tanks.
- A comprehensive data collection and analysis system should be developed to improve statistical analysis of accident causes.
- Additional research should be conducted to 1) determine the life stages of plants and animals that are most sensitive to ammonia and 2) evaluate the toxicity and sublethal effects of ammonia on these organisms.

From this work, it was determined that the likelihood of an ammonia flash fire is small, because, generally, there is insufficient heat transfer to provide the vapor phase needed to sustain the fire.

A paper on the use of ammonia in energy-related applications (Bomelberg 1981) was prepared as a result of this study.

LPG Research Assessment

J. G. DeSteese, P. J. Anderson,*
D. N. Gideon,** W. E. Martinsen***

The overall objective of this task is to evaluate safety and environmental control issues relating to the production, transportation, storage, and use of liquefied petroleum gas (LPG). The resulting information will assist the DOE/EP in developing a research and development (R&D) program plan that addresses LPG safety and environmental concerns.

This task has involved the efforts of three subcontractors. Battelle Columbus Laboratories (BCL) provided system descriptions of LPG transportation by pipeline, rail, and truck, and an assessment of the state-of-the-art of release prevention and control in the LPG industry. The Institute of Gas Technology (IGT) contributed descriptions of production, import/export, and peakshaving plants together with barge and ship transportation systems. Both subcontractors and PNL identified and evaluated R&D needs and recommended R&D program elements that address LPG safety and environmental concerns. Another subcontractor, Applied Technology Corporation, reviewed the results and provided insights and recommendations that encompass the point of view of the LPG industry.

Work on this task has resulted in a body of information that includes: LPG characteristics, hazards, and risks; production, transportation, storage, and consumer use of LPG; current knowledge of LPG release phenomena; and the state-of-the-art of release prevention and control measures used in the LPG industry. Based on the knowledge gained in developing this information, a number of specific recommendations were developed for R&D projects that address gaps in understanding LPG phenomena and needed improvements in release prevention and control. A final report (DeSteese et al. 1981) was published.

Special Studies

J. G. DeSteese, W. C. Cliff

The Special Studies Task provides information that contributes to the implementation and management of DOE's LGF Program. In FY 1981, a special study was undertaken to assess the use of water as a simulant for modeling LGF boiling liquid expanding vapor explosion (BLEVE) conditions. In this study information was developed on the dimensionless parameters associated with BLEVEs and rapid phase transitions. The initial analysis of this work indicates that water, at the right vapor density and temperature difference (i.e., difference in the initial liquid temperature and saturation temperature), may be used effectively as a

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***Applied Technology Corporation.

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simulant for modeling vapor growth in LGF thermal nonequilibrium processes.

Other information requested by the sponsor was provided, as needed, to assist the planning and technical surveillance of the DOE Assessment Program.

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• Oil-Burning of Spills

A field test on the combustibility of various crude oils was performed to determine their burning rates, ignition requirements, and the conditions under which combustion will occur. Seven crude oils were tested. The tests show that, under optimal conditions, a major portion of an oil spill can be burned, leaving a residue that is more easily removed and smaller in volume than the crude oil itself. Most crude oils will burn successfully if significant weathering has not occurred.

OIL-SPILL COMBUSTION

W. Wakamiya, S. E. Petty

Combustion is one method that may be used for oil spill cleanup in ocean waters. When crude oil is burned, the resulting residue is more easily removed and much smaller in volume than with other cleanup processes. Also, combustion reduces the spreading of the oil spill. The suitability of using combustion depends on the integrity of the vessel, geographical position of the accident, atmospheric conditions, available manpower, and the type of oil. Oil type is important because burning characteristics depend on the oil's composition.

One objective of this project was to verify a proposed model that described how well various crude oils burn. The model was based on specific gravity and boiling temperature measurements obtained from ASTM distillation curves. Large-scale (2-m pool of oil) burning tests of crude oils were conducted to verify the proposed model.

Another objective of this project was to evaluate the effects of heat addition on burning rates. Coils were placed into the oil to add energy. Data were generated on the differences in burning rates caused by additional heat input.

Seven crude oils, listed in Table 1, were tested. These oils were selected because they encompass the spectrum of crude oil commonly transported in ocean waters. In addition, diesel and Bunker C fuel oils were tested.

In FY 1980, 27 test burns were completed. The seven crude oils were burned at least three times each. Each oil was burned once without heat addition and twice with heat addition.

In FY 1981, 21 test burns were made. Four of the original seven crude oils and Bunker C and diesel fuel oils were tested.

TABLE 1. Crude Oils Tested

Crude Oil	API Gravity	Producing Country
Saharan Blend	44.3	Algeria
Attaka	43.2	Indonesia, East Kalimatan
Es Sider	37.0	Libya
Labuan	36.0	Malaysia, Sabah
Ekofisk	35.8	Norway
Isthmus/Mayan Blend	33.0	Mexico
North Slope	26.8	USA

Samples were combusted in a 2-m burning pan. An initial oil layer of 5 cm was floated on a 32-cm column of water. The entire apparatus was surrounded by water to maintain a constant temperature. The following instruments were used in obtaining data:

- in-pool radiometers
- in-pool thermocouple rakes (34 total thermocouples)
- external narrow-angle radiometers
- external wide-angle radiometers
- level controller (used for burning-rate calculations)
- anemometer and weather station (for ambient temperature, relative humidity, and barometric pressure).

In all, 47 channels of data were taken every 4 sec during a typical test burn. These data were then processed and plotted for ease of interpretation.

The tests in FY 1980 were conducted during the months of June and July. The ambient

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temperatures were warm, 31°C (88°F), and did not represent conditions normally encountered in typical ocean spill incidents. This prompted the tests in FY 1981 to investigate the effects of lower temperatures. These tests were conducted during the winter/spring months of March and April at temperatures between 0° to 10°C.

The following conclusions emphasize major results found during this experimental program.

- Crude oils will burn if a temperature profile can be established and maintained in the layer of oil.

- Combustion can occur for oil layers as thin as 3 mm. Apparently, the critical thickness for burning is less than 3 mm.

- Crude oil combusted mainly via the process of flash vaporization. Entrainment, near the end of a burn, occurred as oil particles were entrained and propelled into the flame zone.

- The distillation model predicted that 35 to 72% of the oil would burn. The actual quantity combusted was 90 wt%. Thus, the model underestimates the degree to which an oil slick will burn.

- Burning rates are a function of the composition of the oil, ambient temperature, and atmospheric conditions. Burning rates declined slightly in colder weather, but all of the oils ignited regardless of the ambient temperature.

- Adding heat directly to an oil pool prior to or during a burn enhanced ignition but did not increase the burning rate significantly.

- Diesel and Bunker C fuel oils burned only when promoters were added.

- As expected, lighter oils ignite more quickly than heavier oils.

The current program concludes that as long as a minimum oil depth exists, a crude oil will burn. Only when significant amounts of energy pass into the supporting water phase will combustion cease. Two additional areas require future research:

1. determine if it is possible to insulate thin oil slicks from the supporting water column by a relatively nonconductive medium;

2. determine if solid primers can supply adequate energy to initiate temperature gradients in the oil necessary for sustaining combustion. Ignition may be the most significant parameter affecting combustion of crude oils. Liquid primers, due to evaporative cooling, may not have been successful in the past because of their inability to provide an adequate heat flux to provide the required temperature gradient.

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• Environmental Control Technology for Shale Oil Wastewaters

The capabilities and limitations of treatment and disposal technology are being evaluated for shale oil wastewaters. Laboratory studies (bench-scale) are being conducted to assess the effectiveness of several physical, chemical, and biological processes for removing pollutants from shale oil wastewaters. Recovery of soda ash from in-situ retort water was explored as a possible approach for minimizing the amount of waste salt to be disposed of while upgrading the fuel value of the residue for incineration to destroy organic pollutants. Wet oxidation and steam stripping of retort water were found effective for removing chemical oxygen demand (COD) and alkylpyridines, respectively.

ANALYSIS, SCREENING, AND EVALUATION OF CONTROL TECHNOLOGY FOR WASTEWATER GENERATED IN SHALE-OIL DEVELOPMENT

B. W. Mercer

Several different types of wastewaters may be generated in the mining and processing steps leading to the recovery of oil from shale. Retort water, produced during pyrolysis of oil shale, is generally the most heavily polluted waste stream; others, such as cooling water, may have a relatively low pollution potential. Most, or all, of these wastewaters can be used to moisturize spent shale from surface retorts, but disposal or reuse must be practiced for in-situ operations. The primary objective of this program is to assess the capabilities of state-of-the-art technology for the treatment and disposal of wastewaters generated in shale oil development.

- Soda Ash Recovery from In-Situ Retort Water

Crystallization experiments were conducted on concentrated Geokinetics retort water to evaluate: 1) potential for recovery of soda ash; 2) reduction of waste salt volume for disposal; 3) upgrading the fuel value of concentrated residue for incineration. In-situ retort waters typically contain high concentrations of dissolved salts and organic matter which tend to interfere with conventional biological and physical/chemical treatment processes. Evaporation has been identified as one of the more promising methods of treating this waste because of the relatively high quality of the water recovered and the small quantity of residue (evaporator concentrate) produced. Incineration of the residue to destroy the organic matter is one of the disposal options being considered for this waste. The high concentrations of inorganic salts, predominantly sodium bicarbonate and sodium sulfate, generally reduce the calorific content of the residue from in-situ retort waters below 5000 Btu/lb of dry solids needed to sustain combustion without additional fuel in an incinerator. A gross calorific value of 2200 Btu/lb of dry solids was measured for a sample of evaporator concentrate produced from a Geokinetics retort water. Based on the composition of the evaporator sump concentrate detailed in last year's report (Mercer and Wakamiya 1981), approximately 30% of the sodium would be associated with carbonate/bicarbonate. Material balance calculations indicate some of the sodium (~12%) may have already crystallized from the sump concentrate before sampling.

Another sample of the same Geokinetics retort water used previously in the bench-scale evaporation study reported last year was evaporated from 130 ℓ to 7.65 ℓ in open beakers (concentration factor 17:1). At this concentration, little or no crystallization or precipitation was observed. Results of analysis of this concentrated retort water are given in Table 1.

TABLE 1. Results of Analysis of Geokinetics Retort Water Concentrate

Constituent	Concentration
Na^+, g/ℓ	100
As, g/ℓ	0.32
Inorganic carbon, g/ℓ	23
Organic carbon, g/ℓ	32
Alkalinity to pH 7.7(a), g/ℓ $CaCO_3$	50
Alkalinity to pH 3.7(a), g/ℓ $CaCO_3$	138
$SO_4^=$, g/ℓ	19
Cl^-, g/ℓ	4.7
SCN^-, g/ℓ	6.2
$S_2O_3^=$, g/ℓ	39
pH, units	9.8

(a)Inflection points in titration curve.

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Based on a pH of 9.8, approximately 25% of the inorganic carbon exists as $CO_3^{=}$, and 75% as HCO_3^{-}. At this ratio, the sodium equivalent to 23 g/ℓ of inorganic carbon is 55 g/ℓ; therefore, a maximum of about 55% of the sodium is recoverable as soda ash (Na_2CO_3). Accurate computation of carbonate/bicarbonate concentrations from alkalinity values is not possible because of the presence of buffering agents in the retort water.

Two approaches were used to crystallize sodium carbonate or bicarbonate from the retort water concentrate. The first involved successive evaporation of the concentrated solution or filtrates to smaller volumes followed by overnight crystallization then separation of the crystals by filtration the next day. The second approach also involved successive evaporations but included additional treatment of the original concentrate and subsequent filtrates with CO_2 to produce sodium bicarbonate, which is less soluble than sodium carbonate. Evaporation of the concentrate to less than 30% of its original volume resulted in substantial crystallization of sulfate. Comparisons of results from two experiments with and without CO_2 treatment are presented in Table 2. Preliminary analytical data also indicate that about one-third of the organic carbon was lost in evaporation of 1 ℓ of concentrate to 300 mℓ and the crystallized product may be contaminated with more arsenic than can be accounted for by residual liquid not removed from the filter cake of crystals. No rinses were employed in these studies.

The results of the crystallization studies indicate that recovery of soda ash is possible from retort water concentrate, but the loss of organic carbon during the evaporation step offsets most of the potential gain in the fuel value of the residue.

TABLE 2. Comparison of Results from Crystallization With and Without Carbon Dioxide

Parameter	Without CO_2	With CO_2
Original volume of concentrate, ml	1000	1000
Number of crystallization	3(a)	3(b)
Final volume of concentrate, ml	300	300
Weight of Na recoverd, g	28	31
Available soda ash recovered, %	51	56

(a)Evaporated to 600, 400, and 300 ml.
(b)Treated with CO_2 at 1000, 600, and 300 ml.

Evaporation of the retort water under reflux could allow much of the organic carbon in the concentrate to be retained, but it would require additional equipment and energy.

- Steam Stripping of Organic Matter from Retort Water

Bench-scale studies were conducted with Paraho retort water to evaluate removal of organic matter as well as ammonia from this wastewater. The steam stripper used in this work consists of a 2-in. I.D. glass pipe packed to a depth of 4 ft with 1/4-in. ceramic saddles. The results of these studies show that more than 90% of the C2-C6 alkylpyridines are removed by steam stripping without reflux. Removal of alkylpyridines is significant for codisposal of retort water with spent shale because of the high stability and mobility of these substances found in groundwater adjacent to spent shale piles.

- Wet Air Oxidation of Retort Water

Results of wet air oxidation experiments with Paraho retort water show 60 and 83% COD reductions at 20 and 120 min reaction time, respectively, at 250°C and 2000 psi. The large initial COD reduction for the 20-min time period is believed to be largely the result of rapid oxidation of thiosulfate to sulfate which produces one mole of sulfuric acid from each mole of sodium or ammonium thiosulfate present in the retort water. The pH of the Paraho water decreased from 8.65 to 1.62 during the initial 20 min and remained near the latter value for the longer reaction time periods. Wet oxidation of the Paraho retort water not only reduced the total COD concentration, but also precipitated a substantial amount of COD. Approximately half of the COD could be filtered out of the treated retort water samples, which suggests the use of sedimentation/filtration process for posttreatment of the effluent from a wet air oxidation unit.

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• Compressed Air Energy Storage (CAES)

The objectives of this project are to identify potential environmental problem areas associated with the implementation of Compressed Air Energy Storage (CAES) technology, to assess the potential magnitude of impacts, and to identify strategies to prevent or control adverse impacts. Research efforts in FY 1981 consisted primarily of continuation of preliminary assessments of probable subsurface effects such as alteration of hydrological and geochemical conditions and an assessment of the legal and regulatory issues associated with CAES technology. Program resources and experience were also utilized in: 1) securing regulatory approval for an experimental facility designed to simulate subsurface conditions imposed by CAES in aquifers; 2) assisting with the development of a siting methodology; 3) performing a siting study for a Midwest utility interested in the technology.

COMPRESSED AIR ENERGY STORAGE (CAES)
ENVIRONMENTAL AND REGULATORY CONCERNS

M. A. Beckwith

Compressed Air Energy Storage (CAES) is a technology for storing excess off-peak electrical energy in the form of compressed air for later use in generating peak-load electricity. During periods of low electricity demand, excess base-load generating capacity is used to power an air compressor at the CAES facility. The compressed air is then stored underground in porous media such as aquifers; in caverns mined from hard rock; or in solution-mined salt formations. During peak-demand periods, the compressed air is released and mixed with fuel in a modified combustion turbine to generate electricity.

As the lead laboratory for research sponsored by the U.S. Department of Energy in compressed air energy storage, Pacific Northwest Laboratory (PNL) established the Environmental Control Concerns Program. The objectives of the program include identification of the environmental and regulatory issues associated with the development of CAES; quantification of the environmental impacts (where possible) and establishment of a data base useful for planning and siting CAES facilities; and identification of necessary environmental control practices or areas of required additional research.

During FY 1981, preliminary assessments of environmental and regulatory issues performed in FY 1979 and 1980 were extended to: 1) produce a report on the legal and regulatory aspects of CAES technology; 2) provide support in the areas of environmental documentation and regulatory compliance to the efforts of the CAES technology program at PNL to construct and operate an experimental facility designed to simulate subsurface conditions imposed by CAES in aquifers; 3) assist in the development of a siting methodology and performance of such a study for a Midwest utility. Results and experience to date indicate that environmental concerns posed by this technology are largely amenable to thorough site characterization and proper selection combined with sound engineering practices. It is anticipated that the program will continue to assist in the design and ultimate operation of the system, and in monitoring subsurface perturbations simulated by the planned aquifer field test. We also anticipate that the program will continue to provide environmental regulatory support. Final documentation of a viable methodology for siting CAES facilities and the results of the one such study performed to date will also be forthcoming in FY 1982.

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• Analysis of Nuclear Fuel Cycles

The operation of nuclear fuel cycle facilities will introduce noxious materials, both radiological and chemical, into the environment through routine discharges of both liquid and airborne effluents. The environmental control implications of continuing to develop existing nuclear fuel cycles and implementing new fuel cycles must be systematically determined so technologies that control or eliminate the discharge of noxious materials to the environment can be developed and demonstrated in a timely fashion. The objective of this program is to identify areas in developing nuclear fuel cycles where 1) inadequate consideration is being given to environmental controls, and 2) environmental control improvements can be justified on a cost/risk/benefit basis to ensure that funds are not expended for control in instances where neither the potential effects nor public concerns warrant such expenditures.

NUCLEAR FUEL CYCLE ANALYSIS

R. L. Aaberg, D. L. Brenchley, A. M. Nolan, J. E. Tanner

A stepwise approach was devised for this project. In any given year, the technical activities address specific issues identified in previous years' work and to changes in the focus and thrust behind DOE nuclear programs. In FY 1981, the program focused on four major areas: advanced uranium recovery, gas-cooled reactor technology, Fast Breeder Reactor (FBR) conceptual design activities, and Light Water Reactor (LWR) uranium utilization improvements.

- LMBR Design Overview

During FY 1981, this task provided an overview and assessment regarding the status of the environmental control technology for the conceptual design study of the Liquid Metal Fast Breeder Reactor (LMFBR). This analysis evaluated proposed system performance characteristics with respect to current standards and existing LWR performance. This work provides the Environmental and Safety Engineering Division (ESED) with an independent assessment of current LMFBR systems.

- Gas-Cooled Reactor Overview

Concurrent with the LMFBR program, DOE is sponsoring research on the gas-cooled fast breeder reactor. During FY 1981, this task provided an independent assessment of the expected performance of environmental control systems associated with this reactor system.

- LWR Fuel Cycle Improvements Overview

During FY 1981 this task focused on an assessment of the environmental impacts of proposed improvements to the LWR fuel cycle. Implementing LWR improvements will require changes in current generation LWR operations. Changes in cycle lengths and the associated large reactivity swings will necessitate changes in burnable and soluble usage and reactor operating conditions. These design changes will alter the production rates of fission products, activated corrosion products, and tritium, and reduce the occurrence of failed fuel assemblies. The purpose of this task was to investigate the potential magnitude of the changes in environmental control associated with implement ng proposed LWR improvements.

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• Analysis of the Fusion Fuel Cycle

The overall goal of this project is to provide an independent review and analysis of the environmental impacts and related control technology implications of fusion power. During FY 1981, the program's objective has been to evaluate the possible effluents and control procedures as applied to fusion facilities currently under construction. The environmental control technology impacts on siting of commercial fusion reactors were also evaluated. The study was divided into three tasks: 1) Neutron Activation Products in Near-Term Inertial Confinement Facilities, 2) Site Suitability Criteria for Commercial-Type Fusion Reactors and 3) Recommendations for Environmental Control Technology Program.

FUSION FUEL CYCLE ANALYSIS

W. E. Bickford, D. A. Dingee
B. R. Leonard, Jr., C. E. Willingham

The analysis of the fusion fuel cycle was divided into three tasks, each of which is described below.

- Neutron Activation Products in Near-Term Inertial Confinement Facilities

A review of near-term facilities for the inertial confinement fusion program was done to evaluate the generation of neutron activation products. The facilities considered included the NOVA-1 facility at Lawrence Livermore National Laboratory (LLNL), the ANTARES facility at Los Alamos National Laboratory (LANL), and the Particle Beam Fusion Assembly (PBFA) at Sandia.

Of the near-term ICF facilities, phase 1 operation of the NOVA project is expected to produce the highest fusion energy yield. Demonstrations of break-even fusion energy gain is expected in FY 1983, with neutron yields of 10^{17} per pulse. Pulse rates are currently put at ~250 per year. As such, the generation of neutron activation products in NOVA-1 will certainly exceed anything expected for near-term ICF facilities. With this in mind, only the NOVA-1 facility was examined in depth. The study focused on the neutron activation of structural materials in the NOVA-1 target chamber. Activation of target materials themselves is important, but target designs are not available for independent review. Likewise, the use of fissile materials in targets during phase-2 operation of NOVA was beyond the scope of this study.

Activation of the NOVA-1 target chambers was estimated by averaging expected neutron fluences to the first wall over time for a 2-year operating period. Fluences through the 12.7-cm (5-in.) thick sphere of aluminum alloy were calculated with the ANISN computer code. Activation rates were then determined using the GLUCKE code, and contact dose rates determined using the ISOSHLD code.

Results indicate that activation of the target chamber in NOVA-1 will be minimal. Contact dose rates on the sphere after two years of operation and one day of decay are estimated at ~1.4 mR/hr. No special shielding is required for such low dose rates. After one year, the estimated dose rates fall to 0.6 mR/hr. These dose rates were conservatively calculated by assuming the entire ~6 m^3 of aluminum in the target chamber (218.44-cm inside radius, 231.14-cm outside radius) were compressed to a solid sphere with a radius of 124.4 cm.

For waste management considerations, the hazard measure (HM) for the alloy chamber was calculated. This is simply the volume of water required to dilute the radionuclide inventory to meet maximum permissible concentrations (MPCs) allowed for the general public. After one year of decay, this was estimated at ~150 m^3 of water, due primarily to the presence of ^{54}Mn. After ten years, this drops to ~1.7 m^3 of water required to dilute the radionuclides to MPCs. As the sphere contains ~6 m^3 of aluminum alloy, the disposal hazards are considered insignificant. Some sort of cutting for packaging and disposal will likely be required, but otherwise the techniques for handling low-level radioactive waste will be adequate.

- Site Suitability Criteria for Commercial-Type Fusion Reactors

The objective of this task was to identify the general requirements for selecting a site for a commercial fusion reactor. Some of the siting requirements have an impact on

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the environmental control measures necessary at a fusion reactor site. Consideration was given mainly to commercial fusion reactor designs that will have to undergo the site selection licensing and environmental analyses before construction and operation of the facility. The NRC, DOE, and state siting guidelines for fission power plants were reviewed to identify the areas applicable to fusion. Calculations of release of radioactive material and dose rates resulting from accidents were reviewed. General siting criteria and their effect on the environmental controls of a fusion reactor were reviewed; a possible regulatory position for commercial fusion power plants was also given.

This task involved evaluating the site selection guidelines for fission reactors to determine the type of siting criteria required to construct commercial fusion reactors. The following subtasks were performed:

Subtask 1. Review of existing NRC, DOE, and state guidelines for siting nuclear power plants.

Subtask 2. Identification of areas where fusion reactor operation would be different from fission reactor operation.

Subtask 3. Characterization of assumptions used to generate first approximation dose rates for various events.

Subtask 4. Identification of fusion reactor operation/accidents that could result in hazard to the public or present a risk.

Subtask 5. Identification of areas where fusion reactor operation would require new standards or different methods of analysis compared to fission reactors and implications for environmental control measures planned for fusion reactors.

Subtask 6. Assessment of regulatory position for siting commercial fusion reactors.

The most significant regulations that the fusion industry would face are the siting guidelines of the U.S. Nuclear Regulatory Commission Guide 4.7; General Site Suitability Criteria for Nuclear Power Stations and NRC Regulatory Guide 4.2; Preparation of Environmental Reports for Nuclear Power Plants. Numerous DOE guidelines on occupational safety, radioactive waste management, exposure limits and other areas of nuclear reactor operation exist. Many of these would be applicable to fusion reactor operation if the facilities were licensed by DOE. This is true of the first few fusion test reactors (such as FED, EPR, and DEMO) and experimental devices, but commercial reactors would not be DOE licensed and would have to comply with NRC-type regulations. Topics covered in NRC Guides 4.7 and 4.2 include items such as geology, seismology, hydrology, population considerations, site preparation, land use, safety considerations, and environmental considerations. The Washington State guidelines for site suitability of energy facilities were examined as an example of state guidelines for power-plant siting. The state of Washington has an Energy Facility Site Evaluation Council whose function is to evaluate potential sites and the environmental aspects of locating an energy facility at a particular location within Washington.

Differences and similarities between fission and fusion were examined. The most significant differences are in the area of potential accidents. In fusion there is no possibility of criticality, but major consequences exist from tritium accidents involving substantial amounts of the total tritium inventory. Other problems such as radioactive waste and proliferation will be of less concern in fusion than they are for the fission reactor industry. There are some unique problems in fusion such as the presence of magnetic fields and the need for large quantities of materials for construction and annual blanket replacement. From an occupational safety viewpoint, the sources of radioactivity at a fusion reactor are:

- tritium
- induced radioactive structures
- radioactive coolant corrosion products
- activated reactor building air.

In case of an accident, only the tritium and coolant corrosion products are considered to be significant. From a public viewpoint (site selection) only tritium seems to be of a major concern for offsite dose calculations.

The accident and dose calculations for the STARFIRE fusion reactor designed by Argonne National Laboratory were used as examples for the siting evaluation task. The following accidents or failures of vulnerable tritium equipment were discussed in the STARFIRE report:

- blanket purge stream ruptures and releases 2 g of tritium

- a blanket recovery unit malfunctions and releases 12 g of tritium

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- pump fails and releases 3 g of tritium, or

- a fueling system fails and releases 13 g of tritium.

The total dose commitment from a fusion reactor releasing 10 g of tritium was calculated to be approximately 150 mrem at 450 m from a 100-m stack. For a ground release, the total dose is about 3×10^4 mrem at 450 m from the accident. Using the NRC limits (25 rem) for accidental release of fission products from LWRs as a guide, the low population zone radius for a fusion reactor would be around 400 m. The other possible releases of radioactivity from a fusion reactor (activated structure, corrosion products, and activated building air) would not result in significant offsite doses to individuals near the fusion reactor site.

Generally, the site suitability criteria set forth in the NRC Guide 4.7 are too restrictive for fusion reactors. In particular, the geology and seismology categories for fission reactors are too restrictive for fusion reactors. In the atmospheric dispersion category, major revisions are necessary to apply them to fusion reactors. The 25-rem accident dose limit is for fission products. The reduced biological hazard of tritium needs to be considered and new limits established. Thus the population zone guidelines need to be revised for fusion reactors. All of the other requirements in the hydrology, industrial, and transportation categories are applicable to siting fusion power plants. For the site selection process, regulations concerning magnetic field exposure are not necessary. Occupational and onsite exposure guidelines for magnetic fields will be necessary, however.

- Recommendations for Environmental Control Technology Program

Based upon the analyses carried out in the first two tasks, an evaluation was performed of the experimental data needs to support the environmental control technology of planned fusion facilities.

Two specific areas were identified during the FY-1981 studies that require additional attention in the environmental control area of fusion reactors. The first topic is environmental control technology for air activation products in fusion facilities. The objective of this program is to identify control measures required to limit the release of air activation species generated during the operation of fusion reactors. Control measures such as ventilation systems and holdup tanks to safeguard against unnecessary occupational radiation exposure and uncontrolled release to the atmosphere will be required in operating fusion reactors. This project will use the air activation data generated in previous ECT studies as a starting point. In these studies a reference Tokamak reactor plasma, blanket, and containment building air model was developed and radionuclide production rates calculated. In the present program, we propose to calculate the air activation source terms for the current FED. In the second phase the existing technology for measuring the concentration of these activated air species will be investigated to see if it is adequate for fusion applications. Measures to limit the production of activated air such as shielding, isolation, and alternate containment concepts will be reviewed. Mechanisms for control of these gases such as ventilation/exhaust systems and holdup tanks will also be characterized. The third phase of this project involves the description and planning of experiments to measure the concentration of activated air species at Tokamak Fusion Test Reactor (TFTR) and Fusion Materials Irradiation Test Facility (FMIT) and a review of the control measures planned for these facilities.

The second area of investigation is the fusion containment engineering in loss-of-coolant accidents at fusion power plants. The purpose of this task is to address the impact of the release of activated corrosion products on the containment and control systems required for fusion power plants. The approach will be to utilize data generated in the Magnetic Fusion Safety Research Program. The circulating inventory of activated corrosion and erosion products has been predicted for helium and water-cooled systems. With the exception of tritium (control of which is being investigated at Tritium Systems Test Assembly [TSTA]), this inventory will be the only source of radioactive materials for release in small pipe break loss-of-coolant accidents. Accident scenarios postulating the large-scale melting and volatilization have not yet been formulated in the safety program. The resultant chemistry and behavior of these materials in the containment will be studied. Containment barriers and technology for control or reduction of aerosols in the building will be addressed. The need for further experimental studies will be examined.

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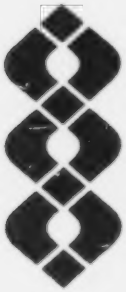

Operational Safety and Environmental Protection

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OPERATIONAL SAFETY AND ENVIRONMENTAL PROTECTION

- **Criteria Development for DOE Decommissioning**
- **Environmental Protection and Assistance**
- **Technical Guidelines/Personnel Dosimetry Calibrations**
- **Health Physics Support and Assistance**
- **Assessment of Criticality Safety**

The responsibility of the Department of Energy (DOE) Office of Environmental Protection, Safety and Emergency Preparedness (EP) is to assure that DOE-controlled activities are conducted in a manner that will minimize risks to the public and employees and will provide protection for property and the environment. The program supports the various energy technologies by identifying and resolving safety problems; developing and issuing safety policies, standards, and criteria; assuring compliance with DOE, Federal, and state safety regulations; and establishing procedures for reporting and investigating accidents in DOE operations.

The Pacific Northwest Laboratory's Operational Safety and Environmental Protection Program contributes to these objectives through projects in the nuclear area. During 1981 the major emphasis continued to be on developing criteria, instruments, and methods to assure that radiation exposure to occupational personnel and to people in the environs of nuclear facilities is maintained as low as reasonably achievable. Particular emphasis has been placed on improving basic personnel exposure measurement and recording programs and improved reporting systems.

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• Criteria Development for DOE Decommissioning

A Guide for Radiological Characterization and Measurements for Decommissioning of U.S. Department of Energy Excess Facilities (PNL-3655) was completed in FY 1981 for the DOE Office of Operational Safety, Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness.

This project was initiated in the third quarter of FY 1979 to prepare guidance for DOE staff and contractors in the planning and implementation of decommissioning operations and in the certification of decommissioned DOE sites. A working draft of a radiological guide was prepared and forwarded for sponsor review in FY 1980. During FY 1981, the guide was completed.

This effort was extended to nonradiological hazardous materials in the last quarter of FY 1980, by developing a questionnaire for DOE contractor sites to identify and quantify nonradiological waste inventories. Although the effort for FY 1981 was to have involved collecting data on DOE sites using that questionnaire, startup of this work was delayed because of possible overlap with the EPA Superfund Questionnaire issued at about the same time. As a result, only a limited data gathering effort was completed in FY 1981 using available DOE Annual Environmental Monitoring Reports and Environmental Impact Statements.

CRITERIA DEVELOPMENT FOR DOE DECOMMISSIONING OPERATIONS

D. H. Denham, C. J. English, Jr.

The primary objective of this project is to prepare guidance for DOE and its contractors in assessing the need for and evaluating the performance of decommissioning operations. This guidance is intended to provide a uniform basis for 1) assessing residual radioactive and hazardous waste inventories at DOE excess facilities, 2) developing environmental risk analyses, 3) making decommissioning decisions, and 4) monitoring for compliance with Federal standards and certifying decommissioned sites meet applicable standards. While this study initially addressed radioactive contaminants, it has been expanded to include other hazardous materials. Both of these areas are described below.

- Radiological Decontamination and Decommissioning

The radiological task of this project culminated in the completion of "A Guide for Radiological Characterization and Measurements for Decommissioning of U.S. Department of Energy Excess Facilities," (PNL-3655) (Denham et al. 1981). The first phase of this task included a workshop in Dallas in April 1979 at which the PNL task leaders, an eight-member DOE special decommissioning task force, and the DOE technical sponsor participated. That initial workshop and a review and analysis of current radiological decommissioning programs, especially those conducted for the U.S. Nuclear Regulatory Commission (NRC) by PNL and by Oak Ridge National Laboratory, provided the basis for planning and preparation of the contents of this guide. A second workshop was conducted at Kansas City in April 1980 to which selected DOE field office and contractor personnel were invited as well as individual representatives of the U.S. Environmental Protection Agency (EPA) and the NRC. Specialists from the major DOE program offices were invited as speakers to provide an overview of current DOE decommissioning programs and program plans.

The radiological guide describes the elements of radiological characterization at DOE excess facilities in preparation for, during, and subsequent to decommissioning operations. The guide's purpose is to provide the user with sufficient information to carry out the decommissioning tasks with a minimum of confusion and to provide a uniform basis for evaluating site conditions and verifying that decommissioning operations are conducted according to a specific plan. The guide emphasizes:

--the need for and suggested methods of radiological site characterization including: historical surveys, environmental pathway analyses, statistical sampling design, and appropriate instrumentation and measurement choices;

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—the need for and emphasis on quality assurance, documentation, and records retention;

—the establishment of a Design Objective approach to setting site-specific contamination limits based on the ALARA philosophy;

—the assignment of numerical values to a "de minimis" or minimum dose level for decommissioning operations.

We expect this guide to be circulated through appropriate DOE field offices and contractor staffs in FY 1982.

- Nonradiological Decontamination and Decommissioning

As originally planned, the bulk of the work for FY 1981 was to have involved collecting data on DOE sites using a questionnaire and guidelines developed during FY 1980. Since a similar EPA questionnaire (required by the recently passed Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA or Superfund]) was received, the sponsor requested that implementation of the PNL questionnaire be postponed until DOE sites had complied with the CERCLA inactive waste site questionnaire.

However, the information provided by the CERCLA questionnaire was limited; hence, we sought additional data including descriptions of activities as well as general geographical, geological, and hydrological parameters. We used two readily available sources, the Annual DOE Site Environmental Monitoring Reports and the Environmental Impact Statements. The Environmental Monitoring Reports give concise descriptions of the sites, although they typically do not contain enough information to identify potential problems related to nonradioactive wastes. The EISs give far more complete descriptions and also describe nonradioactive wastes, although the primary focus is on radioactive wastes and related activities. A shortcoming of these data sources is that they are generally limited to the old Atomic Energy Commission (AEC) sites regulated under the Atomic Energy Act (AEA). Monitoring data are limited exclusively to the AEC sites, and EISs for the non-AEC sites (if available) are very activity-specific.

Adequate data are not currently available to characterize most DOE sites with respect to hazardous chemical contamination. Therefore, it is recommended that future nonradiological decommissioning efforts be directed toward developing a methodology by which to characterize hazardous chemical cont[illegible]tion at all DOE sites. In addition to cha[illegible]terization, the need to develop nonradiological criteria for DOE decommissioning efforts is also recognized. It is expected that this work will closely parallel that performed in development of the Radiological Characterization and Measurement Guide.

REFERENCES

Denham, D. H., et al. 1981. A Guide for Radiological Characterization and Measurements for Decommissioning of U.S. Department of Energy Excess Facilities. PNL-3655, Pacific Northwest Laboratory, Richland, Washington.

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• Environmental Protection Support and Assistance

Technical assistance continued to DOE's Office of Operational Safety in the general area of environmental protection. Assistance with program and arrangements for an information meeting on the Resource Conservation and Recovery Act (RCRA) and other regulatory areas was provided. An updated version of the previously issued Guide for Environmental Surveillance was prepared and issued as a DOE document. Work continued on a companion guide for effluent monitoring at DOE sites. Results from a questionnaire and several site visits on current quality assurance practices in effluent and environmental monitoring at DOE nuclear sites were summarized. Reviews and analyses of dose assessment models available for general use, as well as the methodology employed at DOE nuclear sites for CY 1979, were prepared for inclusion in an eventual report on this technological area. Emphasis for environmental data reporting was placed on nonradiological pollutants, and reports were prepared on potential DOE use of existing EPA and Department of the Army systems for National Pollutant Discharge Elimination System (NPDES) permit tracking, noncompliance reporting, and information retrieval. A prototype data system was developed for nonradiological noncompliance tracking. A computer-based listing of all Environmental Impact Statements (EISs) issued by DOE and its predecessor agencies was developed; a tentative classification system for trackable commitments was devised. A questionnaire was prepared and distributed to DOE sites to elicit information on existing ground-water monitoring practices.

ENVIRONMENTAL PROTECTION SUPPORT AND ASSISTANCE TO DOE/OESD

J. P. Corley, R. E. Jaquish, P. J. Cowley, G. W. Dawson, P. A. Eddy, K. A. Hawley, W. E. Kennedy, M. A. Mueller, I. C. Nelson, D. L. Strenge, B. V. Andersen

The general objective of this program is to provide the Department of Energy's Office of Operational Safety (OOS) with technical support as needed in accomplishing its environmental protection objectives. The intent is to support a number of separate tasks, as requested by the sponsor, with the capability and flexibility to respond quickly to new problem areas and changing priorities as they develop. Task areas addressed during FY 1981 included:

- reviews and comments on proposed regulations, draft DOE orders, and other potential operational impacts;
- assistance with OOS-sponsored information meetings, workshops, and conferences;
- reviews of existing practices and recommendations for environmental and effluent data reporting systems, including annual summaries;
- reviews of existing practices and recommendations for environmental dose assessment;
- reviews and analyses of existing quality assurance practices in effluent and environmental programs;
- assessment of need and feasibility of a follow-up program for DOE environmental impact statement commitments;
- reviews of existing practices and recommendations for ground-water monitoring programs;
- preparation of effluent and environmental guides to supplement DOE orders.

The tasks for EIS follow-on and ground-water monitoring were implemented during the year. The tasks of environmental data reporting and effluent and environmental guides were incorporated from previously separate programs.

DOE Information Meetings and Conferences

J. P. Corley

Assistance was provided with program planning and arrangements for an information meeting for DOE and contractor staff held in November 1980. This meeting focused primarily on the Resource Conservation and Recovery Act, but also covered other environmental regulatory issues. Proceedings of the meeting were furnished to DOE.

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Preliminary planning efforts were made for a fourth DOE Environmental Conference, which was later postponed to FY 1983.

Effluent and Environmental Guide

J. P. Corley

The previously issued "Guide for Environmental Surveillance," ERDA-77-24, which has continued to be requested by other organizations, was updated and reissued as DOE/EP-0023 (Corley et al. 1981). Aside from a new chapter on quality assurance, most of the changes were relatively minor, in the expectation that major changes will be made in a future revision after completion of several of the other tasks under way within this program.

Work continued on a guide for effluent monitoring at DOE facilities. This guide has the same general objectives as the Environmental Guide: to promote greater uniformity in DOE environmental protection and to provide an additional tool for DOE programmatic assessments by supplementing the mandatory requirements of DOE orders with advisories. Numerical criteria were proposed for defining needed sensitivity and accuracy for effluent radioactivity measurements.

Quality Assurance Requirements for Effluent and Environmental Monitoring

R. E. Jaquish

A questionnaire devoted to quality assurance practices was distributed to DOE nuclear sites in 1979 as part of an emergency preparedness review. During FY 1980, 26 completed questionnaires were reviewed and seven follow-up site visits were made. A letter report summarizing the findings and recommendations for additional attention was provided to the sponsor.

Environmental Dose Modeling Review and Recommendations

M. A. Mueller

Work continued on a three-part review of environmental dose modeling. The first part reviews documented analytical models available for use by DOE in assessing radiation doses; it includes atmospheric transport and dispersion, waterborne transport, exposure pathway, and dosimetry models for normal operational releases. The second part identifies the methodology in use at each of the DOE sites preparing annual environmental summary reports for FY 1979, including the data bases and models used. Table 1 shows the analysis form and partial results. The third part of the review will consist of recommendations.

Environmental Data Reporting Systems for DOE Sites

- Annual Environmental Summaries

K. A. Hawley

A draft report, summarizing the data provided in the annual environmental reports from the 27 DOE nuclear sites reporting for 1978, was prepared for sponsor review and comment. A summary report for 1979, expected to be issued by DOE for public information, was also provided. Emphasis in this report is on unusual occurrences, plus the radiation dose commitments received from DOE site operations by the maximally exposed individual in uncontrolled areas and by the populations within an 80-km radius of all DOE sites. Nonradiological monitoring data reported by the nuclear sites were also included.

- Nonradiological Reporting System

R. E. Jaquish

Requirements for annual reporting by the DOE nuclear sites of radiation impacts on the local environment have been provided for many years in DOE orders (previously AEC and ERDA Manual Chapters), and have been supplemented by the Environmental Surveillance Guide. Similar guidance has not been given for nonradiological releases, in part because primary regulatory guidance responsibility lies with other agencies. More detailed guidance for DOE site reporting of nonradiological releases is needed, especially for any noncompliance situations.

During FY 1981, an effort was initiated to review available data-base systems for applicability to DOE sites, both nuclear and nonnuclear (Corley and Cowley 1981). An existing noncompliance tracking system in use by the Environmental Protection Agency and a prototype system developed by the Department of the Army were analyzed and tested. Neither system totally meets the sponsoring Office's needs, in one case because of the limited information provided and in the other because too great an effort would be required to operate and maintain the system (Jaquish 1981).

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TABLE 1. Summary - Environmental Dose Evaluation Methods for 1979 at DOE Sites

DOE SITE	REPORTED INFORMATION FOR 1979																										MODEL INFORMATION REFERENCED													
	SAMPLING DATA											RADIATION DOSE ANALYSIS														AIR DISPERSION				WATER DISPERSION			DOSE MODELS					
	STACK	DIRECT EXPOSURE	AIR	WATER	SEDIMENTS	WELL WATER	FOOD PRODUCTS	MILK	WILDLIFE	FISH	SOIL AND VEGETATION	FENCE LINE INDIVIDUAL	MAXIMUM INDIVIDUAL	POPULATION (80-km)	ANNUAL DOSE (FIRST-YEAR)	COMMITTED DOSE EQUIVALENT (50-YR)	DIRECT EXPOSURE	AIR SUBMERSION	INHALATION	H_2O INGESTION	TERRESTRIAL FOOD INGESTION	AQUATIC FOOD INGESTION (FISH)	OTHER PATHWAYS	GAUSSIAN PLUME	X/Q DATA	STACK MEASUREMENT	ENVIRONMENTAL MEASUREMENT	OTHER	ANNUAL AVERAGE MIXING	EFFLUENT MEASUREMENT	OTHER	ICRP 2	TGLM	RATIO TO ERDAM 0524 CONC. GUIDES	OTHER
IDAHO NATIONAL ENGINEERING LABORATORY [a]		•	•	•		•	•	•	•		•	•	•	•		•		•	•		•		•					•			•			•
NEVADA TEST SITE [b]		•	•	•		•	•	•					•	•		•		•	•							•							•		
HANFORD SITE [c]	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•		•			•	•		•
SAVANNAH RIVER PLANT [d]		•	•	•		•	•	•	•	•	•	•	•	•		•		•	•	•	•			•		•	•	•		•	•			•

(a) FENCEPOST INDIVIDUAL AND TOTAL POPULATION DOSES WITHIN AN 80-km RADIUS OF THE SITE ARE CALCULATED USING DOSE FACTORS FROM NUREG-0172. AIR DISPERSION IS CALCULATED USING THE MESODIF COMPUTER CODE. PUBLIC DRINKING WATER SUPPLIES AND LOCAL WELLS ARE MONITORED FOR RADIONUCLIDE (INCLUDING ^3H) CONTENT.

(b) MAXIMUM INDIVIDUAL AND POPULATION DOSES ARE FOUND FOR ATMOSPHERIC RELEASES BASED ON MEASURED AIR CONCENTRATIONS AND A RATIO TO ERDAM 0524 CONCENTRATION GUIDES. SURFACE OR WELL WATER THAT CONTAINS RADIOACTIVE MATERIALS IS NOT USED AS A DRINKING WATER SOURCE.

(c) FENCEPOST INDIVIDUAL, MAXIMUM INDIVIDUAL, AND TOTAL POPULATION DOSES ARE REPORTED FOR THREE RELEASE SITES ON THE HANFORD RESERVATION. THREE DIFFERENT POPULATION DISTRIBUTIONS ARE USED SINCE THE RELEASE POINTS ARE A SIGNIFICANT DISTANCE APART. RADIATION DOSE FACTORS ARE FROM THE DACRIN, FOOD, ARRRG, AND GRONK COMPUTER CODES.

(d) 70-YR COMMITTED DOSE EQUIVALENTS ARE CALCULATED FOR THE AVERAGE AND MAXIMUM FENCEPOST INDIVIDUAL, THE TOTAL POPULATION WITHIN AN 80-km RADIUS, AND INDIVIDUALS AND THE POPULATION DRINKING WATER DOWNSTREAM OF THE PLANT. THE METHODS OF THE ICRP ARE USED TO CALCULATE THE RADIATION DOSE FACTORS. DEPOSITION RATES ARE DETERMINED BY RAINWATER ANALYSIS. LIQUID CONCENTRATIONS (INCLUDING ^3H) ARE DETERMINED AT MUNICIPAL WATER INTAKES.

In a separate effort, a prototype system aimed primarily at noncompliance tracking, but with additional detail available, was developed using data from the Richland Operations Office as an example. The prototype served the purpose both of providing an example of a state-of-the-art interactive computer system and of delineating the data elements that would be tracked in a comprehensive data reporting system. The prototype will be used as a base to define further the specifications of an operational system.

Environmental Impact Statement (EIS) Follow-On

I. C. Nelson

A computer-based listing of all EISs issued by DOE and its predecessor agencies was compiled, since none was found readily available. Efforts are being made to keep this listing updated and accurate. From this list, a test set was drawn and closely reviewed for determination of apparent environmentally relevant commitments by the issuing agency. The task team devised a tentative classification system for those commitments that seemed significant or major and that could be tracked for future review; the team recommended that the formal DOE Record of Decision should be to indicate those commitments to be tracked. Further testing of these concepts is required before a final report is submitted. Safety Analysis Reports and Environmental Assessments also remain to be assessed as additional sources of environmental commitments.

Ground-Water Monitoring Review

P. A. Eddy

This task is intended to review ground-water monitoring practices at DOE sites, with the expectation that further consistency in programmatic approach can be achieved. A questionnaire, designed to elicit pertinent information, was devised and distributed late in the fiscal year. Insufficient returns were available at the end of the year to permit any conclusions.

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Corley, J. P., et al. 1981. A Guide for Environmental Radiological Surveillance at U.S. Department of Energy Installations. DOE/EP-0023 (ERDA-77-24 Revised), U.S. Department of Energy, Office of Operational Safety, Washington, D.C.

Jaquish, R. E. 1981. Interim Report: Review of EPA's National Environmental Data Systems. PNL-3911, Pacific Northwest Laboratory, Richland, Washington.

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• Technical Guidelines/Personnel Dosimetry Calibrations

A base of technical information is being acquired and developed for evaluating the calibration, design, and performance of dosimeters used at Department of Energy (DOE) facilities. A technical document will be prepared to guide DOE and DOE contractors in selecting appropriate personnel dosimetry systems and calibrations. Draft criteria presented by the American National Standards Institute (ANSI 1978) will be used as a guide for establishing recommended dosimeter calibration and irradiation procedures.

TECHNICAL GUIDELINES FOR PERSONNEL DOSIMETRY CALIBRATIONS

P. L. Roberson, R. C. Yoder, C. D. Hooker, R. A. Fox, R. T. Hadley, K. L. Holbrook, J. M. Selby

The purpose of this project is to assemble information to guide DOE and DOE contractors in selecting personnel dosimetry systems and calibrations. Personnel dosimetry performance, a major concern of radiation protection officials, is strongly influenced by dosimeter calibration techniques. Proper calibration assures that the response of a personnel dosimeter correlates with the radiation dose received by an individual. Errors and uncertainties arising in the calibration are propagated through the entire personnel dosimetry system, often causing incorrect assessments of radiation doses to personnel. The design of the dosimeter influences its performance at energies far from the chosen calibration points. The assignment of doses based on exposure sources may be different from the assignment of doses based on the calibration sources.

This project is divided into three tasks. Task 1 was to develop a variety of calibrated radiation fields for use in Task 2, investigation of the performance of dosimetric systems currently used by DOE contractors. Task 3 is to prepare a guide on personnel dosimetry system performance. Task 1 is complete; task 2 is under way. Task 3 will be performed in FY 1982.

Irradiations were performed in conformance with criteria presented in the American National Draft Standard, Criteria for Testing Personnel Dosimetry Performance, ANSI N13.11 (ANSI 1978). Although the draft standard does not directly address dosimeter calibrations, calibration methods must be selected and employed to be compatible with the irradiation techniques used for dosimeter performance evaluations. The performance tests specified in the draft standard reflect several concepts that have not been routinely incorporated in many calibration programs.

- Task 2: The Dosimeter Performance Data Base

The collection of the data on dosimeter performance was separated into three phases. The first phase consisted of one three-month test procedure as specified in ANSI N13.11 (ANSI 1978). PNL was the testing laboratory, and the participating DOE contractors used their own dosimeter calibrations. In Phase II, PNL provided calibrations for the ANSI N13.11 sources used during the Phase I irradiations. The contractors were asked to recalculate their results for the Phase I dosimeter irradiations based on these calibrations. Phase III consisted of special irradiations designed to test the dosimetry systems under conditions not included in the draft standard. Of particular interest were irradiations using x rays of lower and higher energies, beta-particle irradiations using a less-penetrating energy than ^{90}Sr-^{90}Y, and a mixture of neutron and x-ray exposures. All of the Phase III irradiations were designed to better approximate actual field conditions at DOE facilities.

Eleven DOE contractors participated in the collection of the performance data. Phase I analyses are complete for nine of the contractors participating. Phase II analyses are under way. Less than half of the participants have reported Phase III data. Information concerning Phase III data is not included in this summary. The analysis of the data will be complete by the second quarter of FY 1982.

The irradiations for Phase I and II were performed in accordance with ANSI N13.11 (ANSI 1978). The dosimeter performance was tested for both shallow (0.007-cm) and deep (1-cm) dose equivalents according to the draft standard. The protection categories tested were low-energy photons (x rays),

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high-energy photons (^{137}Cs), beta particles (^{90}Sr-^{90}Y), photon mixtures (^{137}Cs with x rays), photon-beta mixtures (^{137}Cs with ^{90}Sr-^{90}Y), and neutrons (bare ^{252}Cf). The x-ray techniques used were the medium-filtered National Bureau of Standards Techniques, Medium Filter-G (MFG), MFC, and MFI. The performance for each category will be discussed in turn.

The dosimeters of all participating contractors performed well on the ^{137}Cs category. The standard deviations were low, allowing an acceptable performance with relatively large biases in a few cases.

The x ray category was tested for both the shallow and deep doses. The performance for both depths was similar for all participants. Five contractors had no difficulty passing the category with low biases and standard deviations. Two contractors had about 50% calibration differences, causing category failures. One contractor had greater than 200% calibration differences. The large standard deviations reported by this contractor were caused by a problem in the ANSI performance algorithm, not in the performance of the dosimeter. Performances in the ^{137}Cs/x ray mixture category fell midway between the performances with ^{137}Cs and x rays alone. Generally, correcting the x ray performance automatically corrects the ^{137}Cs/x ray mixture performance.

The ^{90}Sr performance was tested for the shallow dose equivalent only. Several contractors had a significant negative bias, causing failures in the category. Performances in the $^{137}Cs/^{90}Sr$ mixture category were complicated by several problems causing failures or near failures. For those with a negative calibration bias for the ^{90}Sr exposures, only the shallow doses were low. A ^{90}Sr-induced signal for the deep dose elevated the standard deviation in one case.

The dominant problem in the bare ^{252}Cf category was a large negative bias for half of the contractors. This appears to be a simple difference in calibration methodologies. Unfortunately, when calibrations were corrected, the standard deviations increased, some high enough to still cause failure in the category.

Some of the calibration differences were due to: 1) calibrating with x ray source spectra unlike the NBS techniques, 2) calibrating with beta-particle sources with energies lower than ^{90}Sr and in very different geometries, and 3) calibrating with neutron sources in high-scatter environments. However, differences in calibration do not necessarily mean that either is incorrect. These other source and geometry arrangements may be more representative of the actual field exposures for the particular dosimeters used.

Less than half of the failed categories were corrected by using PNL calibrations (Phase II). Problems noted were:

- --Dosimeter design deficiencies made it difficult to reconcile the dosimeter response to x rays with responses to ^{137}Cs and ^{90}Sr.
- --Dosimeter design deficiencies allowed beta particles from the ^{90}Sr source to affect the reported deep dose.
- --Design deficiency of the neutron dosimeters allowed a high dependence on neutron spectrum.
- --Design and/or handling deficiencies resulted in high standard deviations in the neutron category.

Seven of the nine contractors reporting Phase I data participated in all categories tested. Two of the seven passed all categories in Phase I.

- Preparation of a Calibration Procedures Manual

Dosimeter performance will be correlated with design and calibration procedures. Design criteria and calibration procedures yielding optimum performance for both ANSI N13.11-specified sources and sources closer to actual field environments will be documented. This information will permit a uniform approach to radiation dosimetry by DOE laboratories. This task will be performed in FY 1982.

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• Health Physics Support and Assistance

Pacific Northwest Laboratory functions as the lead laboratory providing health physics support and assistance to the Division of Operational Safety, Department of Energy (DOE), on special studies principally associated with analyzing the impact of standards, regulations, and engineering and administrative actions on occupational and environmental exposure. Support and assistance are also provided for other specific tasks or special studies identified by DOE as priorities. The designation of lead laboratory in health physics, with an agreement and budget in place, provides the Division with the additional expertise necessary to respond to the many questions and situations that arise during the operation of their numerous energy research, development, and demonstration facilities.

HEALTH PHYSICS SUPPORT AND ASSISTANCE TO THE DEPARTMENT OF ENERGY

L. G. Faust, J. M. Selby

The health physics support and assistance program is divided among several tasks described below.

Field Testing, Calibration and Standardization Techniques for Improved Neutron Spectroscopy

L. W. Brackenbush

Personnel neutron dosimeters are highly energy dependent. Knowledge of the neutron fields in which they are used is required in order to properly evaluate them. The purpose of this task is to develop three types of neutron spectrometers from commercially available components, calibrate each spectrometer, and test them under field conditions. This should provide a means of accurately assessing neutron dose.

Three spectrometers were assembled and are operational:

- a multisphere spectrometer, which has poor resolution but a wide energy range;
- a ^{3}He spectrometer, which has poor resolution but operates well between 30 keV and 1 MeV; and
- a NE-213 liquid scintillator spectrometer, which has reasonable resolution but operates at neutron energies above 1 MeV.

The NE-213 spectrometer demonstrated problems eventually traced to the commercial photomultiplier tube base. The signals from the commercial unit were distorted so that it was not possible to easily differentiate neutron and gamma events on the basis of pulse shape. With these limitations, the spectrometer can only operate above 1 MeV, but by building a special transistorized tube base it should be possible to separate neutron and gamma pulses at energies as low as 300 keV.

With the exception of the NE-213 spectrometer, all of the spectrometers have been calibrated and tested with monoenergetic neutrons at the PNL Van de Graaff and the National Bureau of Standards filtered neutron beam facility.

Computer codes have been obtained or written for unfolding the data from the spectrometers. One such code was obtained from the Naval Research Laboratory and modified to run on a minicomputer. The new code, which is simpler, faster and much less complex, should allow the multisphere spectrometer to be better utilized. Two simple computer codes were also written to determine the response of TLD-albedo and other types of neutron dosimeters for a given neutron spectrum determined by the spectrometer measurements. The codes provide energy correction factors for more accurate evaluation of dosimeter results.

Field measurements were made to test the spectrometers under actual operating conditions. Measurements were made at a plutonium fuel fabrication facility, a fast breeder reactor, a plutonium storage vault, and a large accelerator site. Results of these measurements will be published in a forthcoming document. Studies with the instruments at the Fermi National Accelerator Laboratory suggest the need for more rugged instrumentation. The measurements were made outside and above the beam tubes buried in the earth. Problems with positioning, intermittent thundershowers, and power line surges due to the power requirements of the accelerator magnets suggest that more portable and perhaps battery-operated equipment for field use would be beneficial.

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Development of a Standard Neutron Instrument

L. W. Brackenbush, K. L. Soldat, R. C. Yoder

Neutron fields in which personnel dosimeters are calibrated and used must be better characterized in order to improve the accuracy of neutron dosimetry. The objective of this work is to investigate the use of tissue equivalent proportional counters (TEPC) as a standard neutron instrument for increased accuracy in characterizing neutron fields.

There are several advantages in using tissue equivalent proportional counters:

- TEPCs directly measure absorbed neutron dose in the tissue-equivalent medium.
- TEPCs are self-calibrating through use of the proton drop point or an internal alpha check source.
- It is possible to separate gamma and neutron doses by the differences in energy deposition in the counter; thus, TEPCs can be used in mixed fields.
- By appropriate algorithms, it is possible to determine quality factors and therefore dose equivalents.

The tissue equivalent proportional counter has several problems that have prevented its more widespread use:

- A gain shift problem prevented its use in low dose rates (long data collection times). This problem was traced to outgassing from the tissue-equivalent plastic walls. The problem was solved by 1) heating the Shonka-A-150 muscle-equivalent plastic under a vacuum to remove volatile materials before the plastic was molded into a counter and 2) using "clean room" assembly techniques.
- The TEPC was a laboratory instrument not suitable for field measurements. In its usual form, the TEPC or Rossi Counter is fragile and easily damaged if dropped or subjected to mechanical shock. This problem was overcome this year by developing a rugged version of the counter with a single wire anode and field shaping insulators.
- The data analysis, especially for the derivation of quality factors, is complicated and involves microdosimetric concepts that are not familiar to most health physicists. A computer code called "TEPC" has been written to analyze the data, and a document describing it will be issued shortly.
- There are some philosophical differences in the way quality factors are derived. In the Monte Carlo computer code calculations used to determine fluence-to-dose equivalent conversion factors, the gamma rays originating from $H(n,\gamma)D$ reactions are included in the neutron dose. With the TEPC it is impossible to separate $H(n,\gamma)D$ reactions from external gamma sources, so no gamma contribution is included as part of the neutron dose. This results in higher quality factors measured by the TEPC for low-energy neutrons below about 50 keV.

The tissue equivalent proportional counter may be useful as a more accurate method of determining neutron dose equivalent for calibration sources than the method given in American National Standards Institute standard ANSI N13.11 (ANSI 1978). In the current standard, flux is calculated at a point given the neutron source strength, and applying prescribed flux-to-dose equivalent conversion factors. Unless special precautions are taken, such factors as anisotropy scatter from the source holder, air scatter, and scatter from the walls of the room are ignored.

Using an inverse square measurement technique with tissue equivalent proportional counter measurements, it is possible to measure the neutron dose including contributions from source anisotropy and scatter. This technique assumes that the neutron dose measured at a point can be separated into three components: 1) the direct source contribution, 2) the room scatter contribution, and 3) the air scatter contribution. The mathematical model assumes the room scatter component is almost constant throughout the room and that air scatter is almost negligible; this is a reasonable approximation near the source in the center of a large room. Under these conditions, the plot of the dose equivalent times the square of the distance from the source versus the square of the distance can be developed (see Figure 1). The intercept gives the direct source contribution, and the slope gives the room-scattered neutron contribution. In a small room 5 m wide by 12 m long by 4 m high, the room-scattered component of neutron dose at 1 m from the source is about 14%. In the center of a much larger room 10 m wide by 15 m long by 9 m high, the room-scattered contribution to neutron dose is only 7% at 1 m from the source. Significant calibration errors can arise unless these room-scattered contributions are determined.

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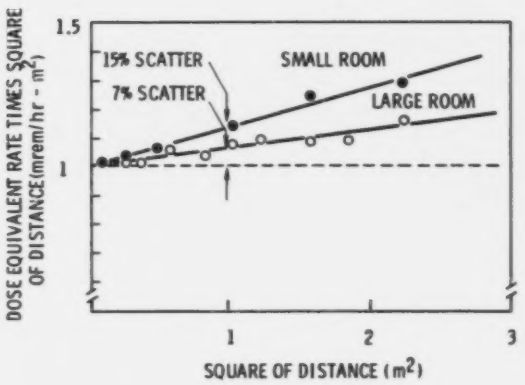

FIGURE 1. Inverse Square Measurements with Tissue Equivalent Proportional Counters to Determine Room-Scattered Component of Neutron Dose Equivalent

Characterization of DOE Facility Emergency Preparedness

T. H. Essig, G. L. Laughlin, B. L. Murphy

In 1970, a study was initiated at the request of the U.S. Atomic Energy Commission and the Advisory Committee on Reactor Safeguards to characterize emergency preparedness capabilities at nuclear sites. The primary emphasis of that study was the capability of then-current instruments to cope with emergency conditions. Five reports (Selby and Unruh 1971; Selby et al. 1972; Andersen, Selby et al. 1974; Andersen, Selby et al. 1976; Bramson, Selby et al. 1976) were issued based on the study. The purpose of this task is to upgrade, as appropriate, the information/data base contained in the series of five reports.

The initial effort was to send a detailed emergency preparedness questionnaire to DOE contractors through the respective Field Offices. This questionnaire, which was sent out in August 1980, consisted of 15 information modules for nine subject areas:

- Administration
- Security
- Transportation Accident
- Emergency Medical Capability
- Effluent Monitoring
- Environmental Surveillance
- Meteorological Monitoring
- Communications
- Quality Assurance/Control

The computer-assisted tabulation of responses was not completed until August 1981 because of continued funding constraints for this task. Responses from 30 Field Office organizations to approximately 340 questions were analyzed.

Subsequent activities in this program will include site visits (where necessary to clarify responses to questions), evaluation of the data, and publication of a report summarizing the current state of DOE emergency preparedness.

Occupational Exposure Registry Upgrade Study

J. J. Fix, B. L. Murphy

The current DOE repository for occupational radiation exposure records for DOE and DOE contractor employees has been used since 1968. Input requirements are currently specified in DOE Order 5484 (DOE 1981) and have remained generally unchanged throughout the history of the repository. Attempts to utilize repository information to evaluate particular aspects of DOE's radiation exposure experience have generally not been successful. This study is examining feasible alternatives for upgrading and improving the repository.

Specific baseline information was recently required to evaluate DOE experience or potential impact with respect to guidance included in proposed revisions to current radiation protection standards. This information included:

- cumulative lifetime external exposure for current employees;
- occupational exposures when internal and external exposures are added according to International Commission on Radiation Protection recommendations (ICRP 1977) or Environmental Protection Agency proposed methodology (EPA 1981);
- limiting occupational doses to 0.5, 1.5, 2.5, or 5.0 rem per year (DOE 1981a);
- increasing the assessment of neutron dose equivalent by a factor of between 3 and 10 (NCRP 1980; Brackenbush et al. 1980; Murphy, Munson and Selby 1981).

To obtain the necessary information, questionnaires were sent to DOE offices and contractors. The data provided an overall evaluation for DOE operations. The collection and analysis process is slow, cumbersome, and perhaps more important, must be repeated if additional information becomes

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necessary. The difficulty in concluding the studies emphasizes the need for a repository that contains these data.

Several potential alternatives to upgrade the repository were identified following a review of existing occupational exposure records at the repository (Fix et al. 1981) and at DOE facilities (Fix, Selby and Vallario 1981). Submission of annual individual doses to the repository was recommended as the best alternative to significantly upgrade the repository within a couple of years. This alternative has several advantages:

- The repository could become a source of information on true radiation exposure for DOE operations.
- The format for submittal of information to the repository would be simplified.
- The repository could uniformly analyze the data, thus eliminating site-to-site differences.
- Eventually, individual occupational exposure histories for all employees engaged in DOE operations would be available.
- The revised input format would permit flexibility to incorporate new requirements as necessary.

Implementation of this alternative will require a revision to DOE Order 5484.1 as well as an upgrading of the repository to accept the additional information.

Annual Exposure Report Upgrade

B. L. Murphy, J. J. Fix

Since 1969, a report summarizing occupational radiation exposures at DOE facilities has been prepared annually from data submitted by contractors to a central repository. The format for these reports has remained essentially unchanged in all the intervening years. Because of a lack of technical discussion in these reports, the tabular data presented have not been readily understood. To correct this, an analysis of the data available in the repository was performed. Following this, a prototype DOE annual report was prepared using information from the 1979 summary report. The report included expanded technical narrative and data illustrations. The 1980 data were received in mid-August and subsequently incorporated into the new report format. Both reports have been submitted to DOE for publication.

The Impact of a Proposed Change in Neutron Quality Factor

B. L. Murphy, L. H. Munson, J. M. Selby

The National Council on Radiation Protection and Measurements (NCRP) suggested a change might be required in the maximum permissible dose limit for neutrons. One possible approach to reducing permissible neutron dose would be to increase the Quality Factor (Q) by factors of 3, 6, or 10. A study was initiated to assess the impact of such a change on radiation protection programs at DOE facilities. To accomplish this, a series of questions concerning specific aspects of radiation protection programs was sent to selected DOE contractors. Findings were published in a report, "The Impact of a Proposed Change in the Maximum Permissible Dose Limit for Neutrons to Radiation Protection Programs at DOE Facilities," (Murphy, Munson and Selby 1981).

The total number of personnel monitored for neutrons during the calendar year 1979 was 24,787. Of this number, 342 received a neutron exposure equal to or greater than 10% of the dose equivalent index. All of the contractors responding, with the exception of one, have data systems that distinguish between neutron exposure and exposure to other types of radiation. Most of the contractors could distinguish between beta, gamma, and neutron exposure. However, three respondents could only distinguish neutron exposure from exposure to all other types of radiation. Retrieval of the type of historical data requested would require extensive computer programming or hand searching of records.

A major research and development effort to provide neutron dosimeters and routine survey meters capable of detecting 50 mrem of fast neutrons would be required by a majority of the respondents if the Q is changed by a factor of 3, 6, or 10 to accomplish the suggested dose reduction. Many respondents hoped to upgrade the accuracy of current neutron measurements by tightening quality control procedures and taking more neutron spectra. Extensive facility modification such as the installation of intrusion detectors, permanent barricades, expanded change rooms, and additional shielding would be required by many of the contractors. Concern was expressed that additional shielding

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could severely limit available space and inhibit technical operations. In one case, additional shielding could force a complete shutdown of a program because of a lack of space. Assuming that funding is available for facility modifications and additional personnel, probably none of the respondents would need to abandon current operations if the Q value were changed. However, facility modifications would delay some programs, and some activities would be reduced to minimize personnel exposure.

Most contractors would require an increased work force. The extent of the increase varies with the change in Q value and the size of the operation. The strengthening of radiation protection programs would be necessary if the Q value is changed. Purchase of additional neutron instrumentation and neutron spectrometers will be necessary. It will also be necessary to alter the dosimetry system, revamp record-keeping systems, and tighten general controls. Additional training will be required.

High-Efficiency Particulate Air Filter Experience Survey

E. H. Carbaugh

A study of the experience with high-efficiency particulate air (HEPA) filters at DOE sites was performed for the DOE Airborne Waste Management Program Office and Exxon Nuclear Idaho Company. The purpose of the study was to provide an initial overview of the reasons and magnitude of HEPA filter change-out and failures to aid in directing future HEPA filter technology development. The study was begun in 1980 and concluded in 1981 with the issuance of the document, "Survey of HEPA Filter Applications and Experience at Department of Energy Sites," (Carbaugh 1981).

Results indicate that approximately 58% of the filters were changed out in the 1977 to 1979 study period and some 18% of all filters were changed out more than once. Most change-outs (60%) were due to the existence of a high pressure drop across the filter, indicative of filter plugging. The next most recurrent reasons for change-out were leak-test failure (15%) and preventive maintenance service-life limit (12%). An average filter service-life was calculated to be 3.0 years with a 2.0-year standard deviation. The labor required for filter change-out was calculated as 1.5 manhours per filter changed.

Filter failures occurred with approximately 12% of all installed filters. Most failures (60%) occurred for unknown reasons. Handling or installation damage accounted for another 20% of the failures. Media ruptures, filter frame failures, and seal failures occurred with approximately equal frequency at 5 to 6% each. Failures attributed to faulty filter construction or media-to-frame sealant failure were negligible.

Subjective responses to the survey provided some indication of problems field personnel perceive:

- a need for improved acid- and moisture-resistant filters
- filters should be more readily disposable as radioactive waste
- a need for improved personnel training in filter handling and installation
- a need for pretreatment of air prior to HEPA filtration.

Bartlesville Energy Center Radiochemistry Lab Decommissioning

C. D. Corbit, T. H. Essig, C. D. Hooker, B. J. McMurray, L. H. Munson, J. M. Selby, J. M. Taylor

In response to a request from DOE/OES, PNL has provided health physics support to the Bartlesville Energy Technology Center (BETC) in planning and executing the decontamination and recommissioning of a radiochemical laboratory. The basic plan was developed during FY 1980. In FY 1981 the work involved technical review of the five D&D proposals, technical review of the D&D procedures developed by the contractor, development of a quality assurance program, technical oversight and third-party radiological surveys. Additionally, PNL staff were present during the seven-week D&D effort as direct support to BETC in observing the D&D work, reviewing the packaging and shipment of all waste, and the preparation of final release records.

All facility locations were successfully decontaminated to background radiation levels. The facility will present no radiological risk to future inhabitants. The facility was "declared" usable following decontamination by the contractor. Currently, the facility is being modified for other purposes by the Department of Energy BETC.

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PERSONNEL NEUTRON DOSIMETER EVALUATION AND UPGRADE PROGRAM

J. J. Fix, L. W. Brackenbush,
G. W. R. Endres, M. R. Thorson,
P. L. Roberson, K. L. Holbrook, L. G. Faust

A program was initiated during FY 1981 with PNL as the lead laboratory to:

1. evaluate response characteristics of personnel neutron dosimeter systems in current use at several DOE laboratories, and

2. develop improved neutron detection techniques to be used as personnel neutron dosimeters and/or instruments.

- Evaluation Phase

Evaluation of neutron dosimeters from twelve DOE laboratories was completed during FY 1981. This effort involved about

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2500 dosimeter irradiations at PNL and the National Bureau of Standards (NBS) utilizing neutrons of several energies and doses. Irradiations were repeated for subsequent statistical analysis.

The data and analyses will be presented in the forthcoming document entitled, "Response Characteristics of Selected Personnel Neutron Dosimeters." The document does not associate response information with individual laboratories or dosimeters, but it does evaluate observed dosimeter results for accuracy, precision, lower dose detection, and energy response.

A meeting was held in Boulder, Colorado during September 1981 to allow each laboratory to observe and comment on the information obtained. In addition, each laboratory was provided with a complete record of its individual data.

- Improved Neutron Detection

Approximately $450K was provided to fund ten proposals during FY 1981 and an approximately equal sum has been identified for FY 1982. Several DOE laboratories as well as universities and private companies are involved in the program. The results of some of these studies were presented at the Eighth DOE Workshop on Personnel Neutron Dosimetry held in Louisville, Kentucky June 18-19, 1981. The proceedings of this workshop have been published as PNL-SA-9950 (Fix 1981).

Prototype dosimeter and/or instrument developments are being evaluated to determine their neutron response and potential for upgrading the existing capability. Commercial manufacturers are involved in this phase of the program, and they are being encouraged to manufacture the developments with attractive market support. Field measurements of neutron dose and spectra are also being conducted at certain DOE laboratories. This information, along with the measured dosimeter response, will allow a determination of the accuracy of field neutron measurements.

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• Assessment of Criticality Safety

A study was completed to assess nuclear criticality safety in eight major DOE facilities and to assess the effects of various types of possible improvements. The data show that the safety performance after 1965, compared to prior years, was considerably improved, indicating that overall safety programs have been effective.

ANALYSIS OF CRITICALITY SAFETY

E. D. Clayton

The results of this study are summmarized in a document entitled "Assessment of Criticality Safety in DOE Facilities" (Lloyd et al. 1981). The accident statistics in DOE operations show that the fatalities caused by nuclear criticality accidents are small compared to other accident categories. Data on criticality safety violations were collected from eight major facilities. These data were categorized by severity indexes and causes were assigned. A total of 421 violations were used in the data base for analysis in a fault-tree model. Calculations were made using the fault-tree methodology to show expected improvement in safety (reduction in probability of a criticality accident) for a fixed reduction in the number of criticality violations. Based on this analysis, about equal emphasis should be placed on reducing mechanical failures and operator errors as efforts in these two areas will likely produce the most significant improvements in safety. A criticality safety infraction form was prepared to facilitate uniformity in recording data on infractions for subsequent analysis. Discussions with nuclear safety specialists working in the field instilled confidence that criticality safety is being handled by concerned, capable, and knowledgable persons.

Two reports on a similar but less comprehensive study have been made previously (Lloyd et al., 1977; Lloyd, Heaberlin and Clayton 1979). The collected data were analyzed with the ACORN and MFAULT computer codes (Carter 1977; Pelto and Purcell 1977). From these analyses, the probability of the inadvertent occurrence of criticality was estimated, and the most likely contributing events were identified in the summary report.

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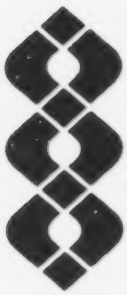

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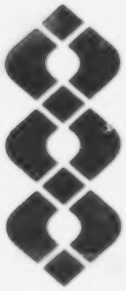

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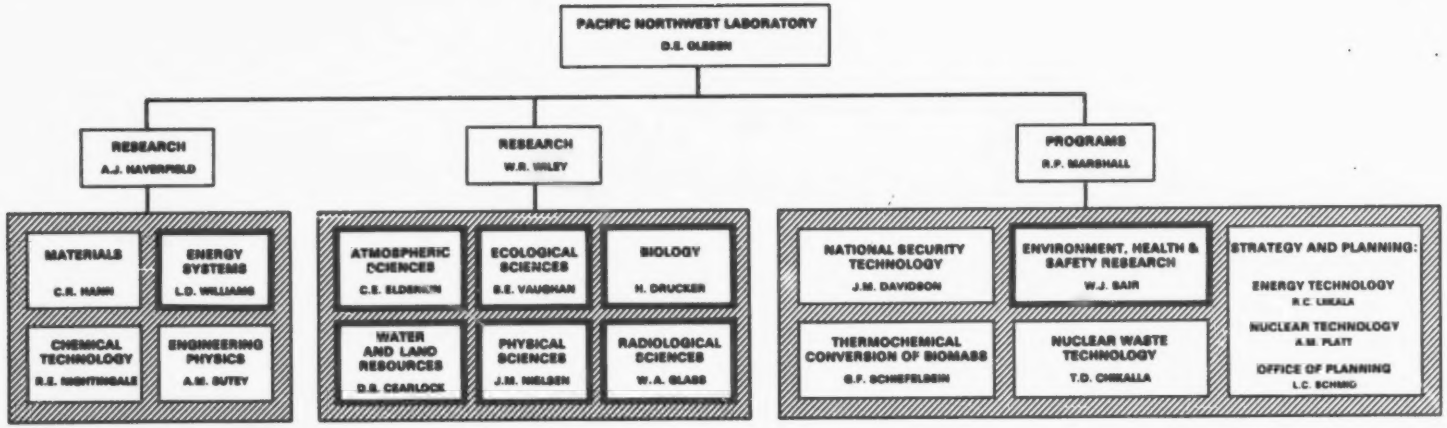

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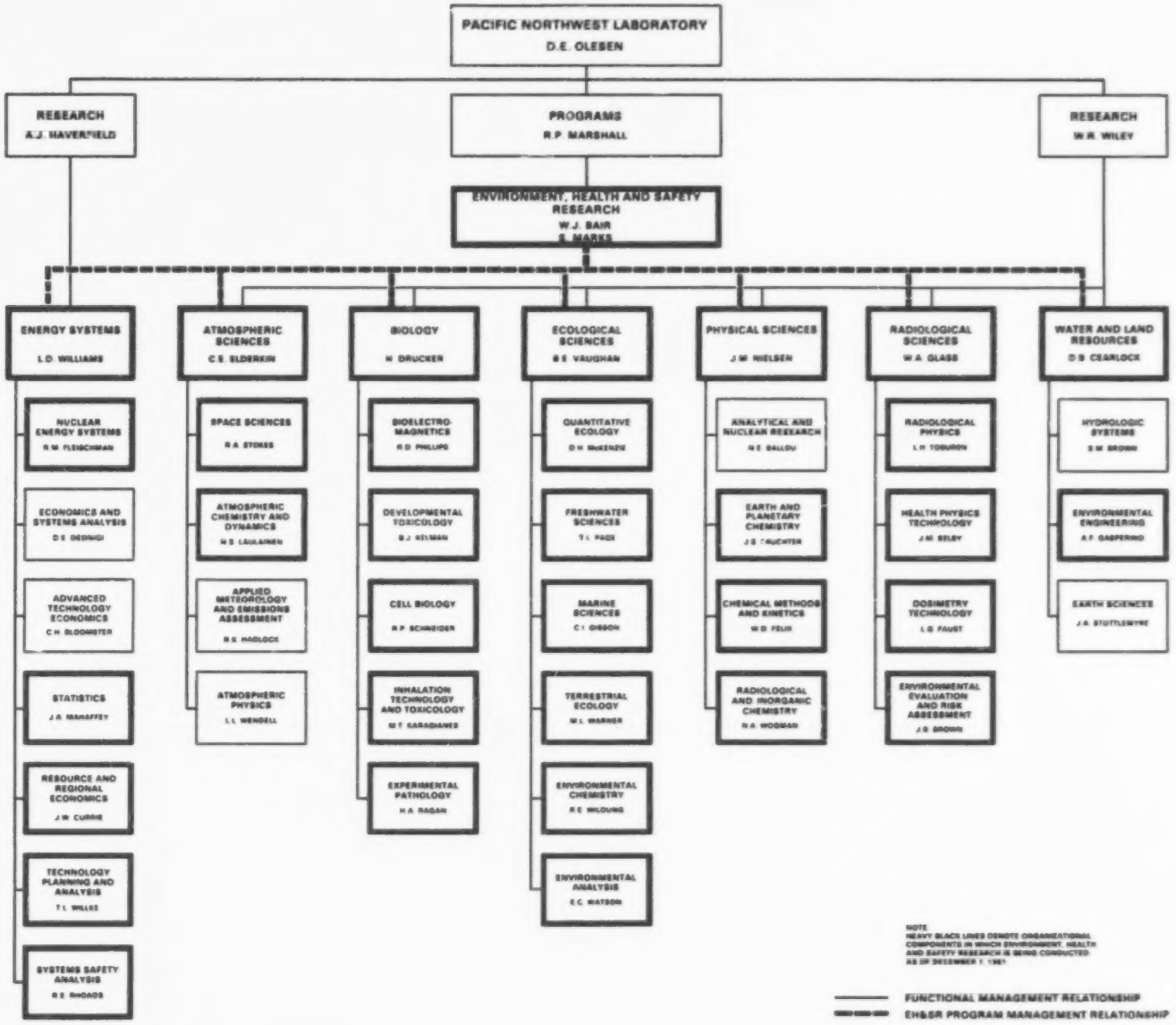

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